JOURNAL OF

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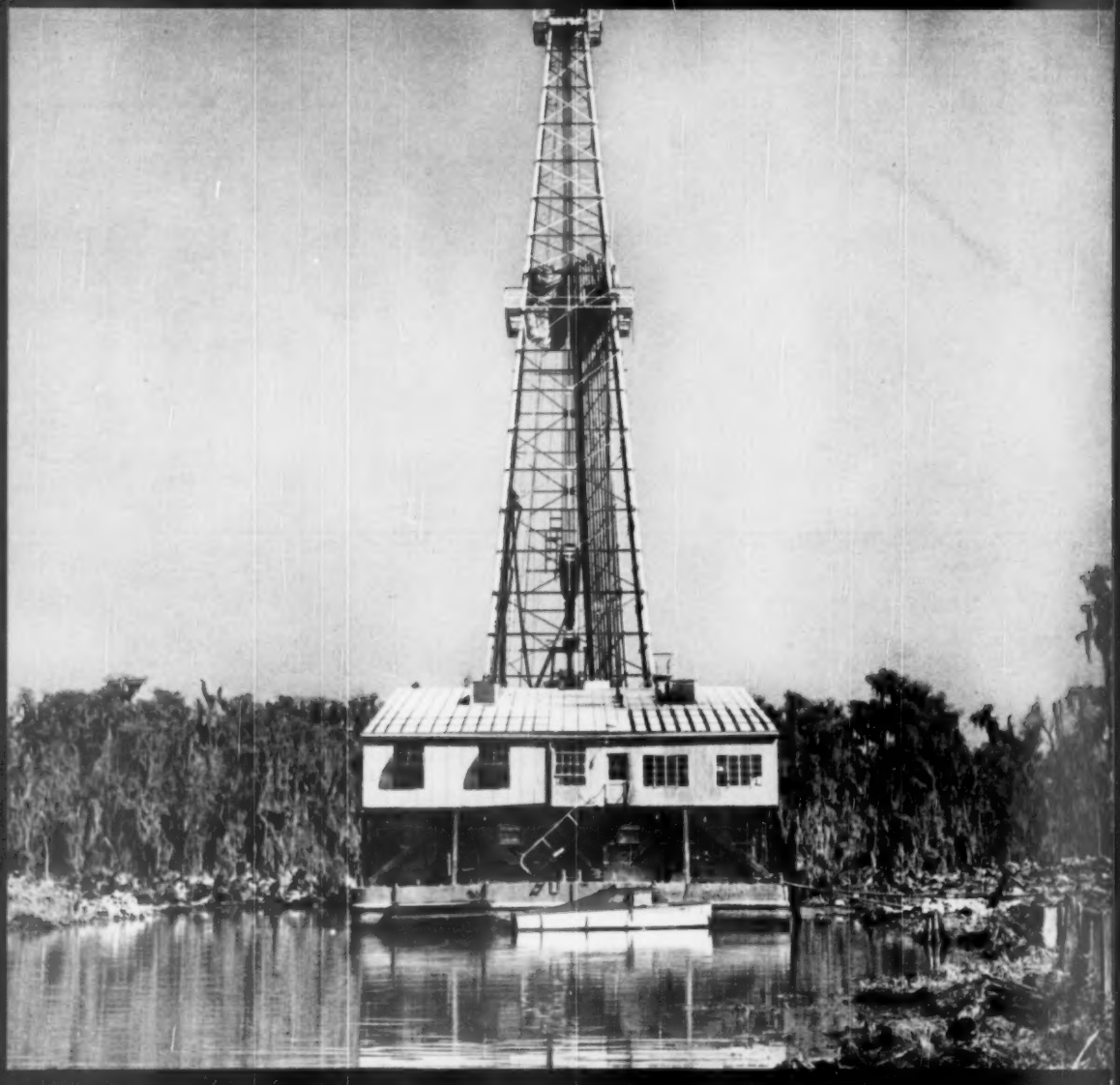


Fall Meetings Issue

SEPTEMBER, 1950

O'HARA LIMESTONE
IN
CANEY MOUND EAST FIELD
UNION COUNTY, KENTUCKY

18

Mud (Aquagel): R_m 2.0 at BHT
Bit Size: 8¼"
Spacings: AM = 16"
AM' = 55"

LOG ANALYSIS

1) Water saturation S

R_w = 0.065 ohm—samples from adjacent wells
F = 35—laboratory analysis from cores in adjacent wells
$R_o = FR_w = (35)\ (0.065) = 2.3$ ohms
R_t = 125 ohms

$$S = \sqrt{\frac{2.3}{125}} = 13.6\%$$

2) Porosity p

$$p = \sqrt[m]{\frac{1}{F}} = 17\% \text{ for } m = 2$$

"MICROLOG" —indicates good permeability from 2516' to 2535'

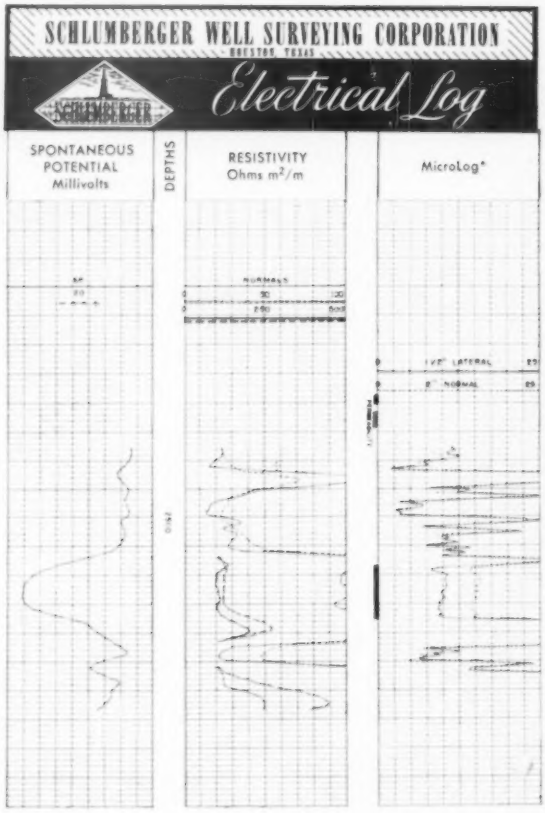
CORE ANALYSIS

Average Porosity 17.4%
Average Water Saturation 20%

PRODUCTION RESULTS

Perforated: 2512' - 2535'
Potential: 2955 bbl/day after acidizing

*"MicroLog" is a trade mark of the Schlumberger Well Surveying Corp.



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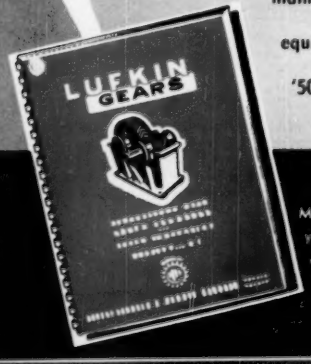

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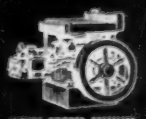
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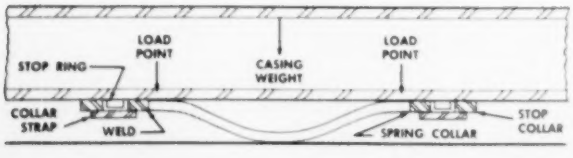

THIS SIMPLE ILLUSTRATION REVEALS THE IDEAL IN SPRING DESIGN AND MOUNTING, WHICH IS FOUND ONLY IN THE BAKER MODEL "G" CASING CENTRALIZER. Note how the load point is imposed directly upon the casing; and how the properly "contoured" spring is free to move along the smooth surface of the casing as the spring deflects under compression. There is no chance for concentration of stress to cause a permanent set, or to result in breaking the spring. Note that ample clearance exists between Stop Rings and Spring Collars to accommodate the increased length of the springs which results from their complete flattening as the centralizer passes dog-legs or tight spots in the hole.

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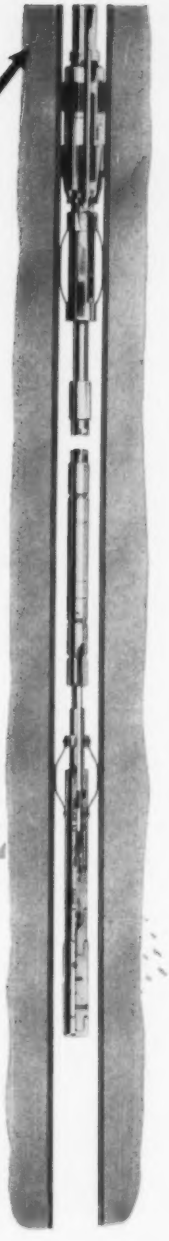

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TABLE OF CONTENTS

Editorial Features — Section 1

ENGINEERS AND POLITICS, by A. C. RUBEL 9

ACIDIZING FUNDAMENTALS, by Paul W. Morrison . . . 10

ENGINEERING DEVELOPMENTS IN LOCAL SECTIONS . . . 15

NEW ORLEANS FALL MEETING PROGRAM AND ABSTRACTS . 16

LOS ANGELES FALL MEETING PROGRAM AND ABSTRACTS . 23

Petroleum Transactions

A STUDY OF RESERVOIR PERFORMANCE OF THE FIRST GRUBB POOL, SAN MIGUELITO FIELD, VENTURA COUNTY, CALIF., By Wayne E. Glenn 243

VOLUMETRIC BEHAVIOR OF OIL AND GAS FROM A LOUISIANA FIELD I, by H. H. Reamer and B. H. Sage 261

CRITICAL ANALYSIS OF THE EFFECT OF WELL DENSITY ON RECOVERY EFFICIENCY, by W. O. Keller and F. H. Callaway 269

1949 Production Statistics

OIL AND GAS DEVELOPMENTS IN ARKANSAS, By Donald H. Mackay 131

OIL AND GAS DEVELOPMENTS IN NORTH TEXAS, By W. G. Sinclair 151

OIL AND GAS DEVELOPMENTS IN THE ATLANTIC COASTAL PLAIN, by E. W. Berry 166

Institute Affairs — Section 2

DRIFT OF THINGS, by Edward H. Robie 1

Personals . . . . . 2 Membership 4

Employment Notices . . 5 AIME Meeting Calendar . 8

Advertisers' Index . . . 8

On the Cover . . . This month's cover picture, the first in the long history of this publication, symbolizes the oil industry as it is pursued in the Delta district of Southern Louisiana. Nearby New Orleans is the site this year of the Petroleum Branch Fall Meeting where AIME members from far and wide will gather to discuss current technological advances. Photographer Leon Trice has captured the Louisiana atmosphere with his picture of a derrick in the bayou.

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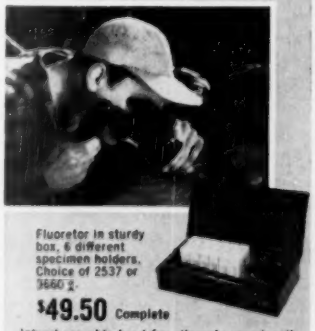

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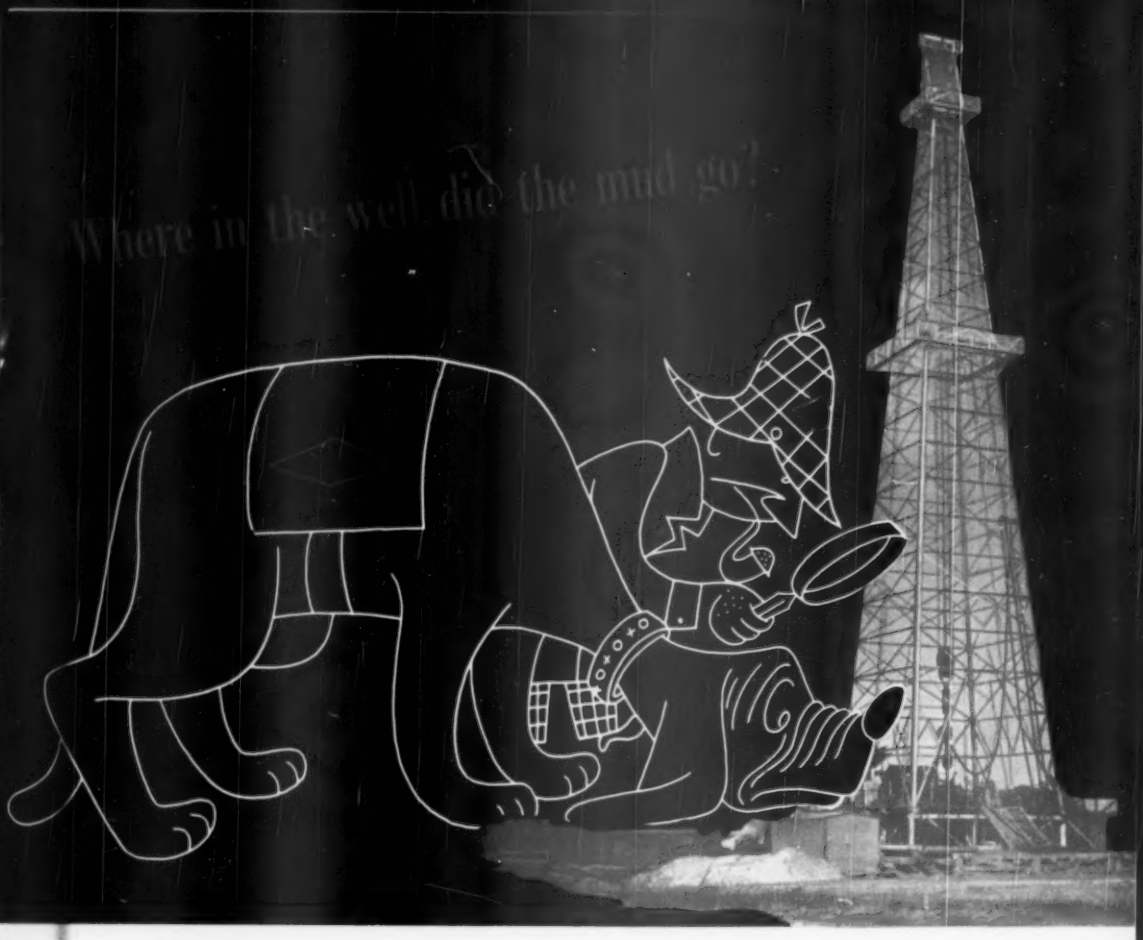

DOWELL SPINNER SURVEY located thief formation accurately when lost circulation threatened drilling

When remedial work is necessary to restore lost circulation, a key question is the exact location of the one or more thief zones. An accurate source of this information is a Dowell Spinner Survey, one of the Electric Pilot services.

Spinner Surveys made by Dowell engineers have made it possible to pinpoint the zones where the loss is occurring. With this information the remedial work can be accomplished more quickly and economically, and with the best possible chance of success. For example: After drilling to 8900 feet, loss of returns occurred when the mud weight was increased. No satisfactory material could be found to restore circulation, so a Dowell Spinner Survey was made. This showed the mud loss was occurring between 2195 and 2300 feet. This zone was squeezed off and drilling continued with full circulation.

Location of thief zones is only one of the proved uses of the Spinner Survey. Ask your Dowell engineer about using a Spinner Survey to determine the relative permeability of exposed zones in a producing or injection well, the relative production of zones in a producing oil or gas well, the location of holes in pipe and leaks in casing seats and bottom hole plugs.

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Editorial Comment—

ENGINEERS AND POLITICS

By A. C. RUBEL, Member AIME
Vice-President, Union Oil Co. of Calif.

IT HAS never been the custom to bring political discussions into technical organizations such as ours, but in the face of the grave emergency which we now face in both our national and international affairs we should not hesitate to break precedent if by so doing we may be of service.

In November of this year we face a national election where the issues involved place our country squarely at one of the most important crossroads in our history.

On one hand we have the time-proven principles of free enterprise upon which our country has been developed and which have given us a greater prosperity for a greater number of our citizens than has been enjoyed by any other nation in the world.

On the other hand we have the primrose path of the social state which promises security from cradle to grave but substitutes bureaucratic control for freedom, and economic and social regimentation for liberty.

The first road, while leading into an uncertain future, has sturdy, test-proven guideposts for backsights to keep us in line, together with a history of solid accomplishment. The other offers nothing from past experience but failures, misery and slavery, and nothing in the future but untried, hazy and fantastic ideology.

Our decisions are not a party matter but a matter of fundamental national policy, regardless of party lines.

Engineers as a group are not politically minded. We are trained and experienced in the determination of facts and the operation of natural laws.

No matter how appealing it may be to the layman, a structure will not stand nor will a machine function unless it is soundly designed and properly constructed.

TO A disturbingly large number of our present politicians there are no natural laws, and facts are distorted and misrepresented without regard to truth seemingly to attract the greatest number of votes. As a result, our country today stands at this crossroad, and unless and until far greater numbers of our intelligent citizenry refuse to accept economic and social doubletalk as a substitute for sound government and statesmanship, and refuse to trade freedom and opportunity for a doubtful security, and quickly and actively interest themselves in politics at all levels, our traditional American way of life is doomed to oblivion.

Because engineers are intelligent and have as a fundamental tenet of their profession the basic concepts of truth, and because in the past they have been conspicuously absent from all forms of political activity, it is doubly imperative that we become politically active today, not alone in the basic duty of casting our votes but also as workers in the party of our choice, as candidates for public office or in any manner necessary to insure a change in our present economic and social trends.

As engineers associated with the operation of business enterprises, we look with the greatest care to the selection of our executives and our management. We insist on ability, loyalty and character, and the success or failure of our business depends on those qualities.

The Government of the United States is the largest business enterprise in the world, and its management certainly merits just as careful consideration.

Under our democratic system we, as citizens, have a voice by our vote in this selection, but it is a sad commentary on our responsibility that less than 40 per cent of the registered voters bother to turn out for the primaries and 65 per cent is an unusual turnout for the final election.

It is for this reason that well-organized groups, usually more interested in personal than in public welfare, so often and so completely dominate our political affairs; and it is for this same reason that today, in the face of threats to our American way of life and to our very national security itself, we find ourselves with the most mediocre leadership both in elective and appointive offices in the history of our country when the highest type of statesmanship is so desperately needed.

WE, as engineers, must do our part to correct this state of affairs, if not as our patriotic duty as citizens then for the purely selfish reason of preserving those principles of freedom and opportunity which are essential to the very existence of our profession.

The agency which may preserve or despoil our democracy is Congress. If we elect able men to Congress, we can be assured of good government and the return to basic American principles; if we elect or permit to be elected incompetent, irresponsible men, we may expect the same type of irresponsible government.

We as individuals can exercise little influence on the Congress as a whole, but in our own Congressional and Senatorial districts we can accomplish a great deal.

There are enough contested seats in the coming election to determine which road we will take, and we can do our part in the choosing if we will start to work.

It is imperative that we ourselves register and vote, and that we use what influence we have to see that others do likewise. We must affiliate ourselves actively with our party organization and have a constructive part in its activities.

Elections are won only by getting out votes, and votes are gotten out by hard work at the precinct level — by ringing doorbells and getting voters to the polls. It is hard and thankless work, but the organized groups have long since demonstrated it to be the only successful method.

If each member of this organization and all other similar organizations would really go to work at whatever job he can best do, by working in the precinct, by helping financially, and by seeing that his family, his friends and everyone within his influence knows and understands the issues and votes intelligently, there will be little doubt of the outcome.

Let us during the coming campaign lay down our slide rules and become politicians — at least for the emergency.

ACIDIZING FUNDAMENTALS

By
Paul W. Morrison
The Chemical Process Co.

HYDROCHLORIC ACID HAS INCREASED THE PRODUCTIBILITY OF LIMESTONE WELLS IN RECENT YEARS. YET, THE AUTHOR CLAIMS, THIS PROCEDURE HAS CREATED A GREAT AMOUNT OF MISUNDERSTANDING. WHAT IS TO BE DONE ABOUT IT?

IN THE past two decades no innovation in oil field procedure has had a more revolutionary effect on completion and production practice than has the use of hydrochloric acid to increase the productibility of limestone wells. At the same time it is doubtful if any other phase of procedure has been the subject of more misunderstanding or controversy.

The problem has not been facilitated by the fact that practically nothing in the field of acidizing lends itself to the scientific method. Obviously a well that has been treated by one method cannot be treated by a different method under the same conditions. Wells that appear identical from sample logs, electric logs and natural production tests sometimes show a wide difference in production tests after acid treatment under identical conditions of technique. Wells that are treated under different conditions of technique frequently come out equal on production tests. Laboratory investigation of cores from producing formation shows a lack of homogeneity in cores from the same well to say nothing of cores from different wells.

This apparent lack of a valid primary premise from which to develop acidizing theory has resulted in numerous variations in acidizing technique. This is particularly true in areas where large volumes of acid are used but is apparent in all fields where acid treatment is required.

In a recent canvass of five active operators in one area it was noted that each employed a distinctive method of procedure which was used almost without variation in the treatment of each well. As among the group, volumes of acid varied from 8,000 to 20,000 gal, the number of stages varied from one to three, acid concentrations varied from 7.5 per cent to 20 per cent, some used additives and some did not. All of them professed satisfaction with their results and were prepared to show data which proved to their own satisfaction that their technique yielded as good or better results than could be obtained by other methods.

Since the operators alone possess the only data by which the relative success of any technique can be measured, and since so many varied techniques yield satisfactory results, some significance might be attached to the fact that they all have one point in common. They all pump some kind of acid into the formation.

This is not intended as an oversimplification of the problem but an attempt to point up the possibility that the question of acid, as such, may have been overemphasized. Of the two principles involved in any treatment, acid and rock formation, the former seems to have received the most attention. This disproportionate interest in acid and the claims and counterclaims made for various types of acid have added to the general confusion to such an extent that it is not uncommon for unsatisfactory results to be attributed to using the wrong "kind" of acid. In reality the trouble may derive from several other causes.

ACID

The properties of *HCl* and the nature of its reaction with calcareous rock were textbook material long before the advent of oil well acidizing and need not be mentioned here. However, the extracurricular problems that result from handling large quantities of acid under varying conditions of temperature and pressure will bear some discussion. The question of additives also is pertinent. These are of two types which will be termed here chemical and physical. The former is designed to change the chemical properties of acid with the idea that the treating solution should be adjusted to chemical variations in the rock formation. The latter includes the emulsion breakers, detergents, and wetting agents. This type has no effect on the reaction between acid and rock but is designed to facilitate the removal of end products of the reaction.

In the presence of an excess of limestone at atmospheric pressure and temperature and under vigorous agitation, acid is neutralized in a matter of seconds. Under treating conditions acid is reacting in the presence of an excess of limestone under vigorous agitation but at temperatures conditioned by bottom hole temperatures and at pressures which vary greatly.

In this change of condition is found the only factor that has any significance in the control of reaction rates. Under pressure carbon dioxide gas from the reaction is forced into solution. This causes a decided reduction in the rate of reaction. A study of the curves on Fig. 1, 2 and 3 indicates that this retarding effect is operative at 400 psi. Increases in pressure above this point result in further retardation though not in proportion to that achieved in the first break. When it is considered that a 1000-ft column of acid exerts a hydrostatic pressure in excess of 400 psi it is apparent that the retarding effect of pressure is operative in nearly all treatments.

Other factors that affect the rate of reaction are: Chemical composition of the rock, acid concentration, temperature, area contacted, and the nature of the fluid with which the rock is wet. Rates decrease as the magnesium content of the rock (dolomite) increases (compare Fig. 2 and 3) and as the concentration increases (Fig. 4). They increase with the temperature (compare Fig. 1 and 2) and with the area contacted (Fig. 5) and rates are faster with water wet rock than with oil wet rock (Fig. 6).

It will be noted that aside from matters of concentration and injection rates none of these factors are susceptible of any degree of control. Some of them tend to counteract each other

and none of them are of sufficient magnitude to appreciably affect treating methods with the exception of extreme temperatures, and injection rates. With temperatures in excess of 150°F the probability of inhibiting acid for more than a few hours becomes questionable and serious damage may be done to subsurface equipment. Increased injection rates increase the area of contact per time unit and thus increase the rate of reaction.

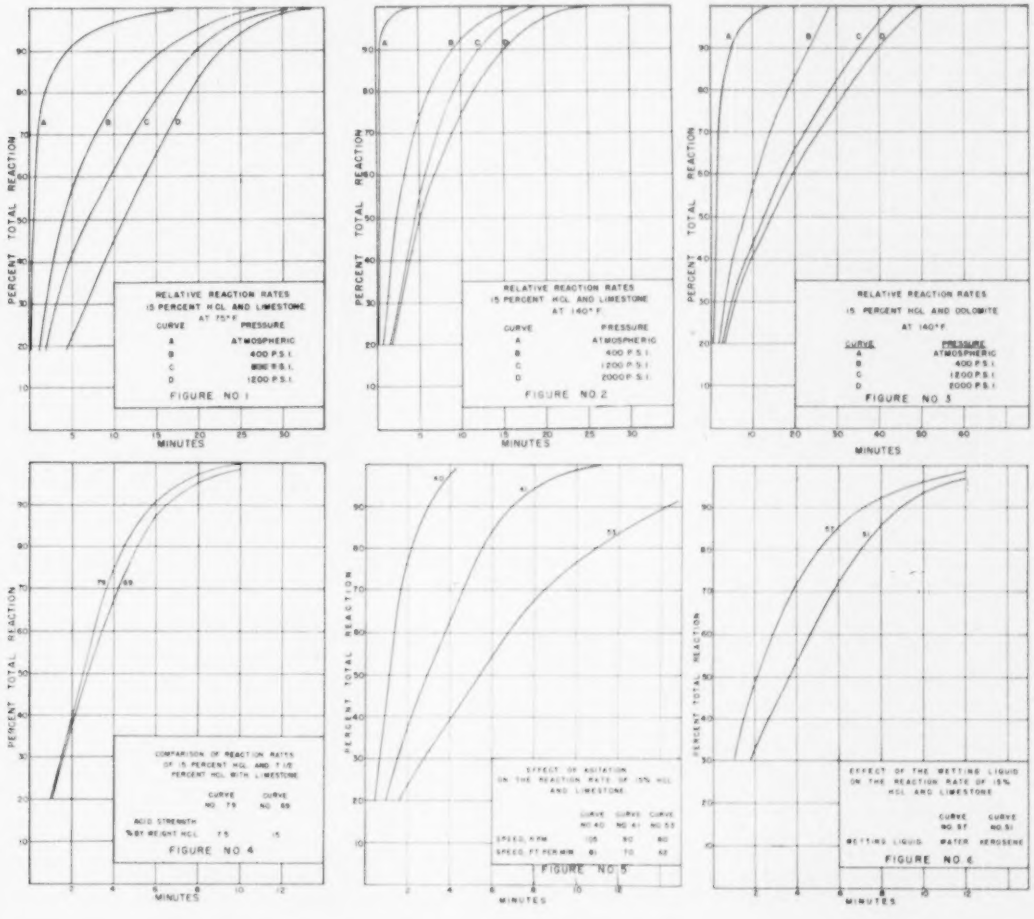
Since it is impossible, except in a few isolated cases, to pump acid into the formation and remove it fast enough to recover any appreciable quantity of unspent acid, additives designed to increase reaction rates are superfluous. Conversely, any retardation of rates that can be achieved by chemical means is insignificant, compared to that resulting from treating conditions, and makes them superfluous. That the theory on which chemical additives are based is fallacious will be indicated later. The "physical" additives have been found to be beneficial under some circumstances particularly when treating in tight low pressure formations. They have been variously presented as "demulsified" acid and "low tension" acid. These terms are misleading to the extent that the agent generally used as an emulsion breaker is also a wetting agent, hence the terms are synonymous when an emulsion breaker is used. There is no evidence to indicate that wetting agents by themselves offer special advantages.

Before attempting to arrive at any definite conclusions on the treating solution, however, a study should be made of the rock formation with which the acid reacts.

LIMESTONE FORMATION

Some time and no small amount of confusion might have been saved in the development of acidizing theory had something of our present knowledge of the nature and performance of lime reservoirs been available at an earlier date. Even now a majority of the data on reservoir performance used in setting up well spacing programs, recovery estimates, etc., is based on a radial flow theory and studies that have been made on sand wells.

Bulnes and Fitting, Jr.,[1] have pointed out that these two types of media differ not only in their chemical and mineralogical composition but in the geometry of their internal void systems. There is no basis in fact to assume that the perform-



ance of the two would be comparable.

The internal void system of a sandstone is conditioned almost entirely by the geometry and sorting of its sedimentary units, hence the porosity and permeability derive from the same source.

In the case of most producing limestones the whole structure has been rendered complex by evolutionary processes that have reconditioned not only the void system but the entire matrix as well. Because of the susceptibility of limestone to dissolution the intergranular system is usually modified by the enlargement of pore spaces or the plugging action of secondary deposition. Various types of water migration may have left fairly continuous channels which together with fractures retained in the rock form a secondary system of permeability distinct from the primary or matrix system. Since the opportunity to experience disturbance increases with the age of the formation the significance of fracturing increases accordingly.

From a mechanical standpoint the chief difference between wells that have a high natural rate of production and those that do not can be explained as a difference in fracture widths, the degree of plugging, and the extent to which channels are interconnected.

It has been noted that in some cases these secondary channels may traverse otherwise dense and barren bodies of rock to connect two or more productive bodies. In speaking of fractured limestones Muskat[2] says, "Such formations are characterized by distributions of fractures, or crevices, throughout the body of the rock. The permeability of the limestone proper is often extremely low and would not alone provide for production rates of commercial importance. However, when such a rock is permeated by fractures it can serve as a reservoir feeding oil into the fractures, which in turn carry the production, directly or through interconnection with similar channels, to the wells. Because these fractures have very high effective permeabilities, even when of extremely small width, the composite system of the limestone body and the fractures may have a resultant flow capacity quite comparable with and often greater than the average sandstone."

Illustrative of the above is Kelton's[3] description of a method of core analysis for fractured limestone cores in which the permeability determination is made on the whole core rather than by the conventional plug method. The core is clamped so that the first determination is made across the direction of principal fracturing to give a value designated as *Kmax*. The core is then turned 90° in the holder and a second determination, K_{90} is recorded. He further describes the results of an analysis, by this method, of cores from a section of Ellenburger formation in the Fullerton Pool in Andrews County. The lack of homogeneity mentioned earlier is illustrated in his classification of these cores into four groups (Table 1). Group 1 (14 samples) consisted of dense samples with limited fracture development. Group 2 (13 samples) had somewhat larger fractures and some open vugs. Group 3 (15 samples) showed more development of intergranular porosity, and Group 4 (7 samples) were intergranular and/or highly vugular. In addition to the special analysis these samples were analyzed by the conventional method with three-fourths in. diameter drilled plugs to give the matrix permeability readings. For purposes of this paper only the part of his table of results dealing with permeabilities is pertinent.

Unquestionably, acid in penetrating the formation will follow the course of least resistance. Matrix porosity and permeability are definite factors in production rates and may affect production increases resulting from acid treatment. Observation of this table indicates that they are not factors to be considered in the selection of a treating solution. This negates the use of treating solutions that are based on an analysis of drill cuttings or matrix.

A study of cores that have been acidized in the laboratory under simulated bottom-hole conditions offers visual evidence in support of conclusions to be drawn from this core analysis report.

It is apparent then that acid treatment can be expected to do nothing more than increase the secondary permeability or in effect produce a lateral extension of the bore hole and thus increase the drainage area. The increase in the production capacity of these channels can be explained by the removal of plugging material and/or the widening of channels.

Relative to this conclusion Muskat[2] offers mathematical evidence to show that a 10,000 gal treatment will penetrate a 25-ft, 15 per cent porosity pay only 10.6 ft radially. In contrast to this, "A moderate treatment of 1,000 gal of 15 per cent *HCl* could dissolve a layer four mm thick for a distance of 300 ft along each side of a fracture in a 25-ft limestone pay." He further states that, "At fracture widths greater than one mm, the production capacity increases as the cube of the width, indicating that the fracture is the controlling factor."

Field experience also tends to confirm these conclusions. Acid treatment in some of the younger Permian formations, in the West Texas area, such as the Grayburg, where little or no evidence of fracturing exists, yields little or no increase in production. Older Permian formations such as the San Andres and Clear Fork, and some of the Pennsylvanian formations yield moderately large increases but require from 8,000 to 20,000 gal to achieve their maximum potential. Very few of the pre-Pennsylvanian formations which are highly fractured require more than 5,000 gal and most of them less than 3,000 gal.[4]

The process of drilling in a well will cause localized plugging that can be removed by a small quantity of acid. This probably accounts for large production increases from small treatments whether in a radial flow system or where extended secondary permeability occurs. Large increases from large volumes of acid can be expected only where extended secondary development exists.

APPLICATION

With these concepts in mind it becomes evident that whether a well has one pay zone or more, the individual zone must be considered as a unit for purposes of acidizing. The salient factor in efficient acidizing technique thus resolves itself into the problem of locating variations in permeability that may exist in a well and then adopting methods of control that will insure the acid treatment of all possible productive zones.

Table 1

Matrix vs Whole Core Data
Ellenburger, Fullerton Field*

Group	1	2	3	4
Matrix Porosity, % Bulk	1.98	1.58	2.56	7.92
Total Porosity, % Bulk	2.21	2.62	3.17	8.40
K_{max}, MD	10	409	23	94
K_{90}, MD	0.6	1.2	10	38
Matrix K	0.3	0.2	0.3	3.7

*From "Analysis of Fractured Limestone Cores," by Frank C. Kelton: *Trans.* AIME (1950) 189, 225.

FIG. 7 — SAN ANDRES, PERMIAN, HOCKLEY COUNTY, TEX., SLAUGHTER POOL, CUT 10 FT BELOW ACIDIZED SECTION, ILLUSTRATING THE ACTION OF ACID THROUGH A SOLUTION CHANNEL.

FIG. 8 — ELLENBURGER, ORDOVICIAN, LEA COUNTY, N. M., BRUNSON AREA, ILLUSTRATING THE VUGULAR POROSITY AND FRACTURES IN THE ELLENBURGER.

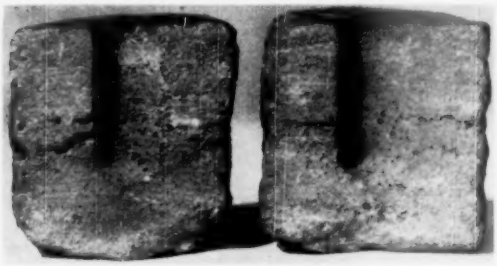


FIG. 9 — SAN ANDRES, PERMIAN, VACUUM POOL, LEA COUNTY, N. M.

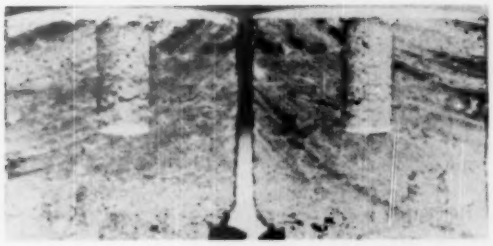


FIG. 10—CLEAR FORK, PERMIAN, DRINKARD POOL, LEA COUNTY, N. M.

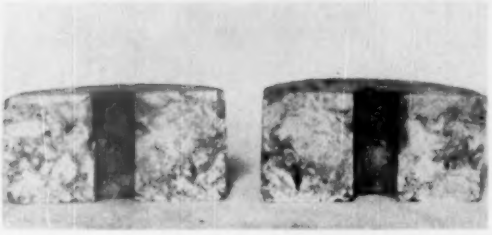


FIG. 11 — CADDO, PENNSYLVANIAN, STEPHENS COUNTY, TEX., ACIDIZED WITH 25 ML 15 PER CENT HCL. PERMEABILITY BEFORE ACIDIZING: 0.195 MD. PERMEABILITY AFTER ACIDIZING: 808. MD.

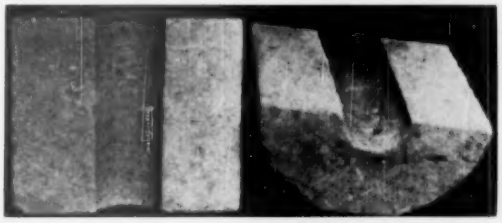


FIG. 12 — MISSISSIPPIAN, STEPHENS COUNTY, TEX., ACIDIZED WITH 750 ML 15 PER CENT HCL. PERMEABILITY BEFORE: LESS THAN .05 MD. PERMEABILITY AFTER: GREATER THAN 3000. MD.

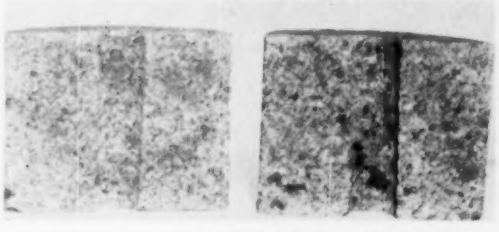


FIG. 13 — BEND CONGLOMERATE, PENNSYLVANIAN, CLAY COUNTY, TEX. (ALLIANCE TRUST CO. NO. 1, 5,995 FT), ACIDIZED WITH 600 ML 10 PER CENT HCL. PERMEABILITY BEFORE ACIDIZING: 1.20 MD. PERMEABILITY AFTER ACIDIZING: 4.53 MD.

These concepts also make possible a better understanding of the function of the treating solution. In penetrating the secondary channels described here the acid is neutralized chiefly by whatever material is contained in or lining the walls of these channels. It is then charged with the further duty of bringing out undissolved solids, insoluble residues, emulsions if any, and of generally scavenging the channel walls. The success of the treatment depends primarily on how quickly and completely this second phase is accomplished. This in turn depends on the amount of secondary permeability and available energy in the treated zone. Zones in which these two qualities are even moderately good present no special problem as they will clean out almost any quantity and concentration of acid residue. This accounts for the relative success of the varied techniques mentioned in the introduction.

Other things being equal, the zone which fails to clean itself properly is the one in which either or both secondary permeability and energy are low. In such cases acid concentrations become important.

Since the inception of acidizing a solution of 15 per cent by weight has been considered as standard. In recent years some field experimentation has been done with concentrations ranging from 7.5 to 28 per cent. The overall results of this testing are inconclusive. Laboratory and field tests together, however, have established these facts: Higher concentrations will (1) cut more solids loose from channel walls, (2) form gel with partially soluble silicate or sulphate compounds, (3) precipitate iron and aluminum compounds from the neutralized solution in a flocculent form and (4) have relatively less water with which to clean it all out. In some instances these conditions have resulted from treatments with 15 per cent acid but the probability increases sharply above this concentration. Aside from this the only other obstruction to a successful clean up comes from a tight emulsion that some types of oil form with acid. This emulsion can be difficult by itself or may aggravate the conditions indicated above.

In addition to control of acid concentration these difficulties can be alleviated by stage treatments and the use of "physical" additives. A small initial stage will clean out quickly and enlarge openings adjacent to the bore hole sufficiently to allow larger volumes to clean out and thus avoid excessive trapping. The additives materially reduce emulsions and generally facilitate the process of cleaning out residues. They make stage treatments unnecessary when the chief obstruction is emulsion.

SUMMARY

By way of summary the following points are worthy of emphasis:

1. A fairly wide range of treating solutions have been found to yield satisfactory results when injected into a productive zone. Except for the few simple precautions indicated in the text, this relegates acid to a secondary though still important position in procedure methods.
2. Production increases from acid treatment in any one zone depend primarily on the extent and distribution of secondary permeability.
3. In multizone wells where variations in permeability exist, overall increases depend on controlled treatment methods that will insure the maximum potential for each zone.
4. From these three points it follows that improved technique must derive from increased knowledge of limestone reservoirs. The diamond core head, electric and radioactivity log and permeability profile, together with natural production tests on the individual zone and production indices where possible, furnish the information essential to a rational and efficient acidizing procedure.

ACKNOWLEDGMENT

Acknowledgment is made to The Chemical Process Co. for permission to write this paper, and for laboratory data, reaction rate curves and pictures of acidized cores. Grateful acknowledgment is also made to B. M. Kingston, G. R. Whitney and M. E. Chapman for their comment and criticism which has been helpful in the preparation of this paper. Thanks is due V. C. White for helping to assemble much of the material which made this paper possible.

REFERENCES

1. A. C. Bulnes and R. U. Fitting, Jr.: *Trans.* AIME, (1945) **160**, 179.
2. Morris Muskat: *Physical Principles of Oil Production*, McGraw-Hill Book Co.
3. Frank C. Kelton: "Analysis of Fractured Limestone Cores," *Trans.* AIME, (1950) **189**, 225.
4. B. M. Kingston: *Acidizing Handbook*, Gulf Publishing Co., (1946).

DISCUSSION

By P. H. Cardwell*[1]

Since the introduction of the acidizing process for oil and gas wells, there has been a number of improvements in the technique used in the treatment of the wells. This particular paper is properly directed to bringing out the various techniques which can be used in the acidizing of wells. There is a need today of more technical papers of this type in which these improved techniques and the applications of each are discussed.

There is a number of factors which must be taken into consideration in the planning of an acidizing treatment. The main factors as stressed in the paper are the physical and chemical properties of the formation. It is a requirement that these properties be thoroughly investigated prior to the acidizing treatment in order to obtain the maximum results. And, in order to handle these and other factors it has been necessary to develop a number of chemical additive agents. The majority of the chemical additive agents used do not have more than an indirect effect upon the rate of reaction of the acid upon limestone or dolomite. Thus, the value of most of the chemical additives cannot be determined by rate of reaction studies.

The chemical additive agents have rather specific uses. Examples of these are such additives as the demulsifying agents and surface active penetrating agents. These agents when present in the acid solution bring about a much more satisfactory introduction of the acid into the formation and also withdrawal of the spent acid solution. Other chemicals are used in conjunction with the acid to help prevent plugging or partial plugging of the flow channels by acid insoluble residues present in the formation. The formations which are acidized are not completely soluble in acid and, as a result, there are always insoluble materials present. Chemical addi-

Continued on Page 3, Section 2

*Member, AIME.
[1]Dowell Incorporated, Tulsa, Okla.

PACIFIC TECHNOLOGY GROUP

Chemistry of Formation Waters

By N. van Wingen

The fourth lecture of the current series on secondary recovery was given by Don Silcox of the Standard Oil Co. of California, July 24, at the Gilmore Auditorium in Los Angeles. Ninety members and guests attended the meeting.

Silcox explained that formation waters normally contain characteristic impurities in the form of dissolved substances and colloidal suspensions. Dissolved materials are salts, gases, and organic matter. Salts most commonly encountered are sodium, calcium, and magnesium, while ammonia and boron are only occasionally present. Iodine is present in very small quantities in most waters, but even so, oil field waste waters are the source of 40 per cent of the iodine used in this country. Carbon dioxide, hydrogen sulfide, and methane are the gases which occur most frequently. Especially at elevated pressure, water may contain significant amounts of methane. Organic material dissolved in oil field waters is most commonly naphthenic matter, acetic acid, and propionic acid. Suspended matter may be oil, clay, silt, corrosion products, bacteria and algae.

The chemical analysis of oil field waters is a standard procedure with most operators. Such analyses can be used to identify the source of water entry in a well, for correlation purposes, to establish the feasibility of utilizing the water for a special purpose such as injection into a reservoir sand or other lease use, and to determine what treatment of the water, if any, is necessary prior to its surface disposal so that it will not harm agriculture.

Water analyses can be reported in a number of different ways. Grains per gallon, parts per million, and reacting value are common means. Graphical presentations of the per cent reacting value, such as the Tickell diagram, are often found to be useful for comparative purposes. The salinity reported should include all ions, but in many instances only sodium chloride is so considered, which is often misleading. It would be preferable if the terminology "chlorinity" were adopted to denote the sodium chloride concentration and salinity used only to designate total ions.

Except for water flooding, formation waters usually contain too many impurities to be used. Thus, it usually is too hard to be used in boilers or engine cooling systems and will almost always be harmful to agriculture. With regard to the latter, Stabler's alkali coefficient is a useful guide. Thus, if this coefficient is greater than 18, the water is excellent for irrigation purposes, while for values below 1.2 it is very harmful.

In order for a formation water to be suitable for water flooding, it must be free of all formation plugging material, it shall not react with the native formation water as otherwise precipitates may form, it must not react with the pore structure (such as clay hydration) and finally, it must be non-corrosive.

In order to meet all of the above requirements, the water most generally requires special handling prior to injection. When a closed system is used, no treatment other than filtration need generally be resorted to. Because of the difficulties generally encountered, however, in keeping a system entirely "closed," the open system is in more general use. An open system may involve several or all of the following treatments: oil separation, iron removal, suspended solids removal, algae and bacteria control, corrosion control, and stabilization of the water.

Iron removal may be accomplished chemically, but as this may cause other precipitates to form, the aeration method is usually the better one. Suspended solids are difficult to remove, but the addition of suitable coagulants, followed by filtration, can usually accomplish removal. Equipment required consists of flocculator, settling basin and filters. The latter may operate either under gravity flow or under applied pressure. Suitable filter material can be sand, anthrafil, magnatite, or a screen plus filter aid.

Algae and bacteria can generally be controlled either by the addition of copper sulfate or by chlorination. The

DON SILCOX
Discusses Formation Waters

former method, however, is not too successful as it will precipitate too readily in oil field waters. Thus, the chlorination method has been found to be the most satisfactory.

Corrosion control presents a great variety of individual problems and many different procedures have to be resorted to to meet special problems. The following techniques or any combination thereof have been used successfully in oil field practice: deaeration, *pH* control, inhibitors, corrosion resistant pipe, and plastic and cement-lined pipe.

Stabilization of water is often effected in order to prevent calcium carbonate precipitation. A small amount of acid or the injection of carbon dioxide is helpful to this end.

In past years many experiments were performed to develop a water treatment which would improve its ability to displace oil. Although conflicting reports have been published, it is the current consensus that neither surface active nor non-surface active agents are successful. The former, whether they be water or oil soluble, are too quickly adsorbed on the sand grains in the immediate vicinity of the well bore, while the latter do not produce the desired effect.

In conclusion, C. R. Dodson, chairman of this lecture series, announced that the next lecture was to be given Aug. 28. At that time, P. G. Nahin of the Union Oil Co. was to discuss the nature and characteristics (geological and chemical) of California sands and clays. ★ ★ ★

PROGRAM

PETROLEUM BRANCH FALL MEETING

New Orleans, La.—Oct. 4-6

ROOSEVELT HOTEL

TUESDAY, OCTOBER 3

7:00 p.m. to 9:30 p.m. — Advance registration and sale of tickets, lobby and mezzanine.

WEDNESDAY, OCTOBER 4

8:00 a.m. to 5:00 p.m. — Registration and sale of tickets, Room D — Exhibits, Room E.

9:00 a.m. to 11:00 a.m. — Technical Session — Grand Ball Room:

WELL LOGGING

*Papers: 31-G — 32-G — 33-G**

9:30 a.m. — to 12 m — Technical Session —Gold Room:

CORE ANALYSIS AND FLOW RESEARCH

Papers: 34-G — 35-G — 36-G — 37-G

9:30 a.m. to 10:45 a. m. — For the Ladies, coffee in the Blue Room.

12:30 p.m. to 2:00 p.m. — Welcoming Luncheon — Address by L. S. Wescoat, President, The Pure Oil Co. — Grand Ball Room.

2:00 p.m. to 5:00 p.m. — Open Meeting, Petroleum Branch Executive Committee — Gold Room.

2:00 p.m. to 4:30 p.m. — Technical Session — University Room:

PHASE RELATIONSHIPS

Papers: 38-G — 39-G — 40-G — 41-G

2:30 p.m. to 5:00 p.m. — For the Ladies, Fashion Show in the Blue Room.

5:00 p.m. to 7:00 p.m. — Men's Smoker — University Room.

8:00 p.m. — to 12 m — Buffet and Supper Dance with entertainment aboard the steamer President — plying the Mississippi.

THURSDAY, OCTOBER 5

8:30 a.m. to 5:00 p.m. — Registration, Tickets and Exhibits, Rooms D and E.

8:30 a.m. to 12 m — Technical Session — Gold Room:

FIELD PERFORMANCE HISTORIES AND OPERATING PROBLEMS

Papers: 42-G — 43-G — 45-G — 50-G

*See abstracts for titles of papers and authors, page 18, Section 1.

8:30 a.m. to 12 m — Technical Session — Grand Ball Room:

PRODUCTION OPERATIONS

Papers: 46-G — 47-G — 48-G — 49-G

9:30 a.m. to 12:45 p.m. — For the Ladies — Walking tour of the Vieux Carre (French Quarter).

1:30 p.m. to 4:30 p.m. — General and Economics Session — Grand Ball Room:

1. **"The Significance of Recent Canadian Oil Developments," by John F. Fairlie, Manager, Coordination and Economics Dept., Imperial Oil Ltd., Toronto, Canada.**
2. **"The Present and Potential LP-Gas Market," by H. R. Thomas and W. R. Thorne, Stanolind Oil and Gas Co.**
3. **Paper yet to be selected.**

1:30 p.m. to 5:00 p.m. — Technical Session — Gold Room.

RELATIVE PERMEABILITY SYMPOSIUM

Papers: 51-G — 52-G — 53-G — 54-G — 55-G

12:45 p.m. to 2:45 p.m. — For the Ladies — Lunch at the Patio Royale and a description of the origin of New Orleans streets by Cartoonist John Chase. Limited capacity.

6:00 p.m. — to 7:30 p.m. — Private cocktail parties.

8:00 p.m. to 1:00 a.m. — Petroleum Branch Banquet, Dance and Floor Show — Grand Ball Room.

FRIDAY, OCTOBER 6

8:30 a.m. to 5:00 p.m. — Exhibits, Room E.

8:30 a.m. to 12 m — Technical Session — Gold Room:

GAS TECHNOLOGY

Papers: 56-G — 57-G — 58-G

8:30 a.m. to 12 m — Technical Session — Grand Ball Room:

DRILLING TECHNOLOGY

Papers: 59-G — 60-G — 61-G — 62-G — 63-G

1:00 p.m. to 4:30 p.m. — Technical Session — Grand Ball Room:

FIELD PERFORMANCE UNDER FLUID INJECTION

Papers: 64-G — 65-G — 66-G — 67-G

NEW ORLEANS MEETING OFFICERS

The foundation work of organizing and planning the myriad of details which make a successful meeting was done this year by the men pictured on this page. They have been working for months toward a Fall Meeting this year that will be mutually beneficial to all members of the Petroleum Branch.

FRED E. SIMMONS, JR.
The Louisiana Land & Exploration Co.
Chairman, Delta Section

EARL KIPP
The California Co.
General Arrangements

CARL E. REISTLE, JR.
Humble Oil and Refining Co.
General Chairman

E. N. VAN DUZEE
Shell Oil Co.
Vice-Chm., Delta Section

E. N. DUNLAP
The California Co.
Advance Arrangements

AIME CLAUDET
Schlumberger Well Surveying Corp.
Entertainment

J. H. RAMBIN, JR.
The Texas Co.
Finance

W. G. SHARP
Continental Supply Co.
Hotel

A. E. ALEXANDER
Hibernia National Bank
Registration

H. M. KRAUSE, JR.
Humble Oil and Refining Co.
Hospitality

H. E. LOWERY
Continental Supply Co.
Hotel

MRS. H. M. KRAUSE, JR.
Ladies Activities

GORDON I. ATWATER
Consultant
Post Convention Tour

L. S. Wescoat to Give Luncheon Address in New Orleans

In the face of new perils the petroleum industry is ready. These are the words of L. S. Wescoat, president of The Pure Oil Co., who has spent 25 years in the industry. On Oct. 4, he will deliver an address at the Welcoming Luncheon of the Fall Meeting in New Orleans. The title of his timely talk is "Petroleum in Peace and War." In it he will state that the public must know what is being done to preserve petroleum for peace and war. Wescoat is a director of the API and a member of the National Petroleum Council. Despite technical and political difficulties and the rapid and endless growth of demand for petroleum, reserves are the highest on record, Wescoat claims. He will elaborate upon these points in New Orleans.

NEW ORLEANS ABSTRACTS AND AUTHORS

Well Logging

31-G

A Progress Report on Quantitative Interpretation of Radioactivity Logs

Robert E. Bush, Lane-Wells Co., Dallas, Tex., and **E. S. Mardock,** Well Surveys, Inc., Tulsa, Okla.

Previous papers have discussed the basic concept of quantitative interpretation of radioactivity logs and a preliminary report of the progress in determining porosities from limestone and dolomite reservoirs. It shall be the purpose of this paper to report on the progress made by the use of absolute zero devices and a more complete quantitative application. Additional discussion of theory underlying the basic concept of quantitative interpretation will be presented with application of this theory to certain sand reservoirs showing the procedure for quantitatively determining saturation of the sand. Illustrations will be of the application of quantitative methods to sand reservoirs in Venezuela, East Texas and other areas.

32-G

An Investigation of the Electrokinetic Component of the Self Potential Curve

M. R. J. Wyllie, Gulf Research and Development Co., Pittsburgh, Penn.

Eight laboratory prepared aqueous base drilling muds and 15 aqueous base drilling muds sampled in the field are used in experimental investigation of the relationship between the streaming potential developed across a mud filter cake and the differential pressure causing filtrate flow. Certain field experiments are described which serve to demonstrate that the total SP developed opposite a formation may be quantitatively accounted for as the algebraic sum of an electrochemical potential and an electrokinetic potential. It is shown that the employment of low resistivity drilling muds is essential if optimum accuracy is desired in the use of the SP curve for the purpose of computing connate water salinities by the electrochemical SP method.

33-G

The Interpretation of Chemical Water Analysis By Means of Patterns

Henry A. Stiff, Jr., The Atlantic Refining Co., Dallas, Tex.

Many problems involving formation correlation, detection of well leaks, tracer studies, drill stem testing, and the identification of water sources are capable of solution by analytical studies of formation waters. Since the physical properties of a water sample are all functions of its total salt concentration, they are of much less value for characterization purposes than the chemical analysis which measures a number of independent variable constituents. The use of patterns presents a novel method for the study of the individual and collective results of chemical water analysis. The pattern system is simple and readily adaptable to a variety of conditions. Varied examples of the applications of pattern analysis to problems encountered in petroleum production operation are given.

Core Analysis and Flow Research

34-G

The Effect of Free Gas Saturation on Oil Recovery By Water Flooding

C. R. Holmgren and **R. A. Morse,** Stanolind Oil and Gas Co., Tulsa, Okla.

Residual oil saturations following water flooding of sandstones can be markedly reduced by maintenance of free gas saturation during the flooding. Results are presented of water floods on a long sandstone core conducted at 500 psi and with static gas saturations varying from one to 30 per cent. Interpretation is presented of the effect of free gas saturation on oil recovered by water flooding as related to relative permeability characteristics. Practical significance as applied to field operations is discussed.

35-G

Interstitial Water Determination By an Evaporation Method

E. S. Messer, Continental Oil Co., Ponca City, Okla.

A knowledge of the magnitude of the irreducible water in a porous medium is so important to petroleum engineering that its determination has become a routine study in most core analysis laboratories. A discussion of the changes in rock surface energy is made to clarify the concept of the irreducible

water content. Using this basic treatment, the experimental results that are obtained by using any one of various fluids are compared with the irreducible water obtained by other methods. An investigation of the results indicates this method has the required prerequisites for production use.

36-G
Capillary Pressure Investigations

Harry W. Brown, Humble Oil and Refining Co., Houston, Tex.

This paper presents results of static capillary pressure measurements made both by the restored state and by the mercury injection methods and of dynamic capillary pressure measurements made by the Hassler technique. The results indicate a variation from sample to sample of the factor used to convert capillary pressures obtained by mercury injection to those applicable to a water-gas system. Static capillary pressures measured by the restored state method were found to be in close agreement with dynamic capillary pressures, indicating that data obtained from static measurements may be utilized with confidence in the solution of dynamic problems of fluid flow. Experimental data are presented on the use of "J-curves" for the correlation of capillary pressure-saturation relations for a number of cores from a particular geologic formation.

37-G
Use of Centrifuge for Determining Connate Water, Residual Oil, and Capillary Pressure Curves of Small Core Samples

R. L. Slobod, Adele Chambers and **W. L. Prehn, Jr.,** The Atlantic Refining Co., Dallas, Tex.

The centrifuge has been found to be an extremely useful tool for determining capillary pressure curves and for establishing connate water and residual oil in small core plugs. Data have been obtained using methods based on earlier work described in the literature demonstrating the reliability of the centrifuge for this work. Some of the advantages of the centrifuge over older methods are (1) rapid establishment of equilibrium, (2) reproducibility of results, (3) simple operational procedure, (4) use of commercially available equipment, and (5) ability to establish connate water, residual oil, or to obtain complete capillary pressure curves in one day or less.

Phase Relationships

38-G
Surface and Interfacial Tensions Under Reservoir Conditions — I Apparatus, II Methane - Water System

E. W. Hough, M. J. Rzasa and **B. B. Wood,** Stanolind Oil and Gas Co., Tulsa, Okla.

The paper describes apparatus which is used to measure surface and interfacial tensions under reservoir conditions by the pendant drop method. The sample under study is introduced under vacuum and does not come in contact with mercury. Experimental data on the methane-water system are presented for pressures up to 15,000 psi and temperatures to 280°F.

39-G
The Phase Behavior of a Natural Hydrocarbon System

Charles F. Weinaug, Chairman, Dept. of Petroleum Engineering, University of Kansas, and **H. B. Bradley,** Dept. of Petroleum Engineering, University of Alabama

The phase behavior of a naturally occurring hydrocarbon system is described. On isotherms immediately below the critical temperature, the same volume per cent liquid was observed at three different pressures for the first time. The shape of the isothermal equilibrium constant curves necessary to predict this phenomenon is discussed.

40-G
Special Considerations in Predicting Reservoir Performance of Highly-Volatile-Type Oil Reservoirs

Alton B. Cook, G. B. Spencer and **F. P. Bobrowski,** U. S. Bureau of Mines, Bartlesville, Okla.

Methods of calculating the volume and composition of hydrocarbon liquid condensed from the produced solution gas that has been liberated in a reservoir are presented in this report. Laboratory data on reservoir oil samples from the Elk City Field et al. are used to show that a large part of the recoverable hydrocarbon liquid from a highly-volatile oil reservoir that is produced by the solution gas-drive mechanism is obtained from the gas-phase fluid entering the producing wells. Data and theoretical considerations are presented in the report to show that the gas-phase in the reservoir can be duplicated in the laboratory, for the declining pressure range in which retrograde condensation occurs, by either the differential or flash gas-liberation procedure.

41-G
Variable Characteristics of the Oil in the Tensleep Sandstone Reservoir, Elk Basin Field, Wyoming and Montana

Ralph H. Espach, U. S. Bureau of Mines, Casper, Wyo.

The data obtained from a U. S. Bureau of Mines sample investigation of oil from the bottom of nine wells of the Tensleep sandstone in the Elk Basin Field indicate that the oil there has unusual varying physical characteristics. The samples were studied for such physical characteristics as the volumes of gas in solution, saturation pressures or bubble points, shrinkage in volume caused by the release of gas in solution, expansion of the oil with decrease in pressure, and other related properties. The data indicate that the sample oil has a saturation pressure of 1,250 psia and 490 cu ft of gas in solution in a bbl of oil at the crest of the structure, and a saturation pressure of 530 psia and 134 cu ft of gas in solution in a bbl of oil low on the flanks.

Field Performance Histories

42-G
A Study of the Dornick Hills - Springer Sand Reservoir, Velma Pool, Stephens County, Oklahoma

Warren B. Davis, Tulsa Division, Gulf Oil Corp.

This paper presents a summary of the results of a study of the Dornick Hills-Springer Sand reservoir of the Velma Pool, Stephens County, Okla. The reservoir is characterized by very steep dips and a relatively thick production section. Its updip productive limit is defined by truncation of the productive sands, and the down-dip limit is defined by deterioration of sand quality rather than by the presence of an oil-water contact. The crude oil is of 29° API gravity, is relatively viscous and was saturated with dissolved gas at the original reservoir pressure.

43-G
Pressure Behavior in the Woodbine Sand

John S. Bell and **J. M. Shepherd,** Humble Oil and Refining Co., Los Angeles, Calif., and Tyler, Tex.

During the last eight years a number of pressures have been measured in the Woodbine sand throughout the East Texas geosyncline. These measurements indicate the basin pressure has been materially reduced by withdrawals, primarily from the East Texas Field and secondarily from the old Fault Line Fields of Limestone and Navarro counties, with the pressure loss varying inversely with the log of the distance from these two main areas of basin withdrawals to the measurement points. Apparently faults located throughout the basin serve as local blocks to continuous pressure gradients.

45-G
Drilling and Production Problems Relating to the Worland, Wyoming Field

L. L. McDonald and **J. I. Morris,** The Pure Oil Co., Chicago, Ill., and Denver, Colo.

Reservoir fluid in the Embar formation at the Worland, Wyoming Field contains hydrogen sulphide in exces of 40 per cent by weight. Precautions necessary to handle safely this extremely toxic high pressure gas, subsurface hydrate formation, severe winter weather at the 4,000-ft elevation and the 10,000-ft depth of the producing formation have combined to make operations at this field one of the most difficult in the nation. There have been two operational phases during the development of the field. The more interesting problems encountered in both of these operational phases will be discussed.

50-G
A Gravel Pack Completion for Exclusion of Gas and Water

Thomas S. West, Al Buchanan and Blanco Oil Co., San Antonio, Tex.

A gravel pack is described which is primarily a selective completion procedure. Although sand screening is achieved, the principal objective is the exclusion of gas and water. Results of the application of the type completion to a number of South Texas fields are shown.

Production Operations

46-G
A Review of Recent Advances in Gas Lift Equipment and Techniques

Louis F. Davis and **Roy M. Willis,** The Atlantic Refining Co., Dallas, Tex.

Important advances made in gas lift equipment and techniques during the past two years have resulted in more efficient operation and have made possible the economical production of wells by gas lift at depths and rates not previously thought possible. Further improvements are in prospect that should increase efficiency and lower costs. Gas lift in the future will be almost entirely with compressed gas, creating a demand for greater efficiency so that compressor investments can be reduced. More and more the industry is using engineering methods and thinking instead of the old trial and error system and is maintaining its position in the artificial lift field.

47-G
The Slip Velocity of Gases Rising Through Liquid Columns

N. Stein, E. B. Elfrink, L. D. Wiener and **C. R. Sandberg,** Magnolia Petroleum Co., Field Research Laboratories, Dallas, Tex.

This paper presents the results of a study of the slip velocity of gases through liquids in vertical tubes, inclined tubes, and vertical annuli. The data were obtained in gas-liquid systems which included combinations of air, propane, and natural gas (over 97 per cent methane) with water, lubricating oils, and crude oils. The 215 data points obtained in this study along with 11 data points reported in the literature are incorporated in an empirical correlation which relates the average slip velocity of gases flowing through liquids with parameters such as gas rate, tube size, ratio of liquid viscosity to liquid density, gas density, liquid density, and the angle of the tube from the vertical.

48-G
Offshore Production and Completion Practices in the Bay Marchand and Main Pass Fields

J. L. LeBlanc, The California Co., New Orleans, La.

The paper covers various proposed methods of transporting offshore oil production to a shore terminal and outlines in detail what the author considers the most feasible method for conditions encountered. This method consists of producing the oil through automatically controlled separators and surge tanks from which automatically operated pumps pump the oil through submarine pipe lines to a shore terminal where barges can be loaded. Directional drilling from steel platforms is outlined. Completion practices are described. The efficiency of various techniques as measured by productivity indices are discussed.

49-G
Experimental Results on Piling

J. R. Morison, J. W. Johnson and **M. P. O'Brien,** University of California, Berkeley, Calif.

The moment distribution on a stepped caisson due to wave action in deep water shows good agreement with the theory. The moment distribution for uniform diameter pile and the effects of size, spacing and shape of piling were found experimentally.

Relative Permeability Symposium

51-G
Measurement and Use of Relative Permeability Data

Uzzell S. Branson, Jr., James A. Lewis Engineering, Dallas, Tex.

The methods used in measuring relative permeabilities of small core samples, some typical relative permeability-saturation relationships, and the effect of variations in relative permeability characteristics on calculated reservoir performance are discussed in this paper.

52-G
Further Developments in the Laboratory Determination of Relative Permeability

B. H. Caudle, R. L. Slobod and **E. R. Brownscombe,** Atlantic Refining Co., Dallas, Tex.

Supplementing an earlier publication, this paper describes the apparatus and technique for obtaining routine relative permeability data on small core samples for both oil-gas and

oil-water flow systems. Theoretical and experimental considerations show that the "end effects" in a dynamic system are small and that the effect of rate in the gas-oil dynamic system is a form of channeling in the capillary system. Results for some preliminary work on a three flowing phase system are presented with a description of the apparatus used.

53-G
Laboratory Measurements of Relative Permeability

J. S. Osoba, J. G. Richardson, J. K. Kerver, J. A. Hafford and **P. M. Blair,** Humble Oil and Refining Co., Houston, Tex.

This paper presents the results of laboratory measurements of relative permeabilities to oil and gas on small core samples of reservoir rock by five methods and describes the influences of such factors as boundary effect, hysteresis, and rate upon these measurements. The five methods used are the "Penn State," the "single core dynamic," the "gas drive," the "stationary liquid," and the "Hassler" techniques. In those methods in which the results are subject to error because of the boundary effect, the error may be minimized by the use of high rates of flow. The results indicate that all five methods yield essentially the same relative permeabilities to gas.

54-G
Experimental Investigation of Factors Affecting Laboratory Relative Permeability Measurements

T. M. Geffen, W. W. Owens, D. R. Parrish and **R. A. Morse,** Stanolind Oil and Gas Co., Tulsa, Okla.

An intensified program to evaluate the factors affecting laboratory measurement of relative permeability is presented as a progress report. All the work is done on a three-section assembly patterned after the Penn State technique. Effects of wettability characteristics, pressure gradients, gas expansibility, migratory water saturation, and saturation hysteresis are studied. Most significant is the work on hysteresis in relative permeability measurements. Indications are that gas saturation following liquid flooding of a gas-saturated sand is of the same magnitude (15 to 50 per cent) as residual oil saturations following water flooding. Evidence is presented indicating that, aside from wettability effects, gas-water and oil-water permeabilities are identical.

55-G
Relative Permeability to Liquid in Liquid Gas Systems

L. A. Rapoport and **W. J. Leas,** The Carter Oil Co., Tulsa, Okla.

An experimental method for measuring the relative permeability of porous media to liquid is described. A theoretical development for calculating limiting relative permeability to liquid values from capillary pressure data is presented, and a comparison is made between the experimental and calculated results. The agreement between theory and experiment is satisfactory. Either method provides information that is adequate for reservoir engineering calculations; however, since the calculated values cost much less, this approach is recommended for routine core analysis.

Gas Technology

56-G
Low Temperature Dehydration of Natural Gas

Louis R. Records and **Dwight H. Seely, Jr.,** Sohio Petroleum Co., Cleveland, Ohio

This paper will present data obtained from field tests of equipment designed for the dehydration of natural gas by auto-refrigeration while expanding from wellhead to pipeline pressures. A wide range of operating pressures, temperatures and water contents have been examined. The limits of application for this type equipment will be shown in the form of a performance nomograph. In addition to dehydration data, the effect of low temperature separation with respect to condensate recovery will be shown.

57-G
Sample Grading Method of Estimating Gas Reserves

D. L. Katz, University of Michigan, Ann Arbor; **C. E. Turner** and **R. D. Grimm,** Phillips Petroleum Co., Bartlesville, Okla.; **J. R. Elenbass** and **J. A. Vary,** Michigan Consolidated Gas Co., Grand Rapids, Mich.

A technique is presented by which well samples and core plugs of the Hugoton dolomite formations are classified by microscopic examination into seven different porosity grades. Quantitative values of porosity and permeability are determined for each grade by a statistical correlation of the core plug test data with the porosity grading system. These quantitative values can be applied directly to the grades exhibited in the well samples for the purpose of estimating the reservoir void space for wells that were not cored. The procedure is described for estimating the gas reserves per unit area for the South Hugoton Gas Field but reserves estimates for the field are not given.

58-G
Looking Ahead at Natural Gas

James E. Pew, Manager of Natural Gas Dept. and Director, Sun Oil Co., Philadelphia, Penn.

Considerable nation-wide attention has been given the natural gas industry recently due to its phenomenal post-war growth and the controversy in the Congress of the United States over the "Kerr Bill." This paper will discuss the growth of the natural gas industry, the present reserves, the effect on fuel markets and the regulation of the industry.

Panel Discussion on Liquefied Petroleum Gas Storage

K. C. Howard, Richardson & Bass; **Charles B. Johnson,** The Chicago Corp., and **G. L. Brennan,** Warren Petroleum Corp.

Drilling Technology

59-G
Plastic Flow Properties of Drilling Fluids — Measurement and Application

J. C. Melrose and **W. B. Lilienthal,** Field Research Laboratories, Magnolia Petroleum Co., Dallas, Tex.

The application of Bingham's law to the behavior of drilling fluids in a rotational viscometer permits the expression of viscometric data in terms of plastic viscosity and yield value, the flow properties of a plastic fluid. A commercially available rotational viscometer is described, and when modified to a multispeed type viscometer, is shown to provide a simple and convenient instrument for the measurement of these properties both in the laboratory and in the field. The data obtained are shown to be useful in defining and understanding mud control problems relating to chemical treatment and to the hydrodynamic behavior of muds.

60-G
Carrying Capacity of Drilling Fluids

C. E. Williams, Jr. and **G. H. Bruce,** Humble Oil and Refining Co., Houston, Tex.

A series of laboratory and field experiments were conducted to determine the minimum annular velocity necessary to remove cuttings, and to investigate the effects of properties of

Continued on Page 7, Section 2

AFTER THE MEETING—A TOUR OF YUCATAN

Within the Archaeological Zone of Chichen-Itza, located 83 miles east of Merida, one may visit (more than) 25 Mayan monuments . . . temples, shrines, pyramids, etc. A great architectural variety of impressing beauty is displayed in these monuments scattered over an area of approximately six square miles.

The above passage is from a current travel folder and contains the usual overload of superlatives and colorful adjectives. But, according to those who have been to Merida, Yucatan, the description is not overdone. For those who would like to see for themselves the beauty of the present and the remains of the past in Merida, the Delta Section called upon Gordon I. Atwater to arrange a post-meeting tour of the ruins in that area as extracurricular activity. What he has come up with is a four-day trip by air that will cost about $198.00, everything included. Members who would take advantage of the tour should contact Gordon Atwater, Whitney Bank Bldg., New Orleans, La. Fred E. Simmons, Jr., chairman of the Delta Section, has this to say about the trip:

"(The) trip can be scheduled to leave at 8:00 a.m. Saturday, October 7, and to return to New Orleans Tuesday, October 10, at 6:50 p.m. Included in the itinerary will be the Chichen-Itza ruins and can be made to include the Uxmal. Lodging will be at the Maya-land Lodge, an extremely picturesque lodge located in the very heart of the archeological zone, and the Hotel Merida. I understand the accommodations are excellent.

"I . . . feel that the trip is extremely worthwhile since the area is off the 'beaten path'—being accessible only by air and an occasional ship. The Mayan ruins indicate the existence of a civilization greater than anything most people ever imagined existed on the American Continent. Even though their highest attainments seem to overlap, to a certain extent, with the latter stages of the Stone Age, their actual accomplishments are amazing. For example, the Mayans have developed a calendar which excels in accuracy our modern calendar and their timing of the year varied with that determined by our most modern methods by some 15 seconds. In addition, without the aid of the wheel and many of the leverage devices we use today, they built some rather massive structures and their art in many ways is equal to the Egyptians. Even though their writing was the crudest form of hieroglyphics, they still seem to have developed a rather high form of culture.

"If we can get from 20 to 25 replies, we will go ahead and make reservations and plan the trip. As an added incentive I point out that the cost of this trip will be deductible from income tax." ★ ★ ★

Hotel Reservations In New Orleans

All persons planning to attend the Fall Meeting in New Orleans, La., October 4-6 should not wait until they arrive in that city before arranging for accommodations. October is a busy month in New Orleans and hotel lodging is not to be had on the spur of the moment.

If you have not made your reservations, you should contact immediately W. G. Sharp, 519 Whitney Bldg., New Orleans, La. A large number of rooms has been set aside for the Petroleum Branch meeting.

In your letter of request, you should state your choice of twin or double room, approximate time of arrival and departure, your choice of three hotels and your name and address. You may choose from the following hotels: Roosevelt (headquarters), St. Charles, De Soto, Monteleone, Lafayette, New Orleans and Jung. Avoid congestion. If you have not done so, mail in your reservation today.

PRODUCTION TECHNOLOGY COMMITTEE

The Production Technology Committee, consisting of five men, is the group responsible for the selection of technical papers which will be presented at the Petroleum Branch Fall Meetings in New Orleans, La., and Los Angeles, Calif. The screening and promotion of papers of a high type was a particularly tedious job, as it always is. But the committee this year can be proud of its work, and the papers, abstracted elsewhere in this issue, are sure to be well received at the meetings.

The committee has as its chairman this year Morris Muskat of the Gulf Research and Development Co. Working with him were Frank Dotterweich, of the Texas College of Arts and Industries, Lincoln F. Elkins, of Sohio Petroleum Co., Earl Kipp, of The California Co., and R. L. Parsons, of The California Research Corp.

(Pictures of Parsons and Kipp are on Page 17 and Page 23 respectively)

MORRIS MUSKAT
Gulf Oil Corp.
Chairman

FRANK DOTTERWEICH
Texas College of Arts and Industries
Vice-Chairman

LINCOLN F. ELKINS
Sohio Petroleum Co.
Vice-Chairman

LOS ANGELES MEETING OFFICERS

Pictured on this page are the men responsible for arranging the Fall Meeting in Los Angeles this year. Credit is due them for the time and effort spent toward arranging a successful meeting.

N. VAN WINGEN
Petroleum Technologists, Inc.
Chairman, Pacific Petroleum Chapter

R. D. TOWNSEND, JR.
General Petroleum Corp.
Arrangements

E. A. GALVIN
Western Gulf Oil Corp.
Luncheon

H. N. MARSH
General Petroleum Corp.
General Chairman

R. L. PARSONS
California Research Corp.
Program

HERMAN SCHALLER
McCullough Tool Co.
Exhibits

J. F. ALEXANDER
Lane-Wells Co.
Publicity

JOHN R. McMILLAN
Fullerton Oil Co.
Dinner Dance

PROGRAM

PETROLEUM BRANCH FALL MEETING

Los Angeles, Calif., Oct. 12-13

ELKS CLUB

THURSDAY, OCTOBER 12

8:00 a.m. to 5:00 p.m. — Registration, sale of tickets, and review of exhibits — Elks Club Ball Room.

9:30 a.m. to 12 m — Technical Session — Elks Club Auditorium.

*Papers: 74-G — 75-G — 76-G**

12:15 p.m. — Petroleum Branch Luncheon at Town House Hotel — Branch Chairman John E. Sherborne presiding.

2:00 p.m. to 5:00 p.m. — Technical Session — Elks Club Auditorium.

Papers: 40-G — 77-G

(Also two additional papers)

*See abstracts for titles of papers and authors, page 24, Section 1.

FRIDAY, OCTOBER 13

8:00 a.m. to 5:00 p.m. — Registration, sale of tickets, and review of exhibits — Elks Club Ball Room.

9:00 a.m. to 12 m — Technical Session — Elks Club Auditorium.

Papers: 73-G — 79-G

12:15 p.m. — Pacific Petroleum Chapter Luncheon and Business meeting at Town House Hotel — Chapter Chairman N. van Wingen presiding.

2:00 p.m. to 4:30 p.m. — Technical Session — Elks Club Auditorium.

Papers: 12-G — 78-G

Also an address by A. C. Rubel, Vice-President, Union Oil Co. of Calif.

8:00 p.m. — Dinner Dance for all AIME members and guests — Rendezvous Room, Biltmore Hotel.

LOS ANGELES ABSTRACTS AND AUTHORS

12-G
Experimental Studies on the Characteristics of the Electrochemical Potentials Encountered in Drillholes

L. De Witte, Geophysical Consultant, Los Angeles, Calif.

Based on measurements of electrochemical potentials across a variety of sedimentary rocks, a generalized theory for these spontaneous potentials is developed. This theory uses the concept of apparent ion mobilities in the interstices of porous rocks. To classify sediments according to their electrochemical behavior, the "electrochemical formation coefficient" is introduced. This coefficient is found to be related to the amount of conductive solids as determined from resistivity measurements. This relation is utilized in an outline of the application of the new derivations to electrolog interpretation.

73-G
Mineralogical Studies of California Oil-Bearing Formations
I. Role of Clays — Methods of Analysis

W. C. Merrill, A. Grenall and **P. G. Nahin,** Union Oil Co. of California, Los Angeles, Calif.

A progress report of an experimental investigation into the role of clay in reservoir performance is presented. The paper gives the reasons for considering clay as a significant component and outlines the objectives of a broad field of study which it is intended to pursue. Descriptions of the analytical methods used are given; these include X-ray diffraction, electron miscroscopy, thin section petrography, cation exchange analysis and infrared spectroscopy. A suite of the more important clay minerals has been assembled and characterized by these methods for use as standards in core analysis.

II. Role of Clays — Analyses of Natural Cores

P. G. Nahin and **R. S. Crog,** Union Oil Co. of California, Los Angeles, Calif.

The methods of analysis developed in Paper I are applied to field cores taken from representative and widely differing strata, especially as regards their susceptibility to damage by fresh water. A particularly clear-cut example of cores from the Stevens Zone and Gatchell Zone in the San Joaquin Valley in which the difference in behavior can be ascribed to differences in the nature of the clay is presented and discussed.

74-G
Relaxation Methods Applied to Oil Field Research

H. Dykstra and **R. L. Parsons,** California Research Corp., La Habra, Calif.

A numerical method for solving partial differential equations in fluid flow is described. The method is applied to core analysis and relative permeability measurements to calculate constriction effects and to calculate the true pressure drop measured by a center tap in a Hassler type relative permeability apparatus. Further applications are suggested.

75-G
Relative Permeability Studies

I. Fatt and **H. Dykstra,** California Research Corp., La Habra, Calif.

Relative wetting phase permeabilities calculated from capillary pressure-saturation data are compared with measured relative permeability data. The equation relating relative permeability to capillary pressure-saturation data is derived by assuming that a porous medium is analogous to a bundle of capillary tubes. The equation includes a term to correct for the difference between fluid path length and length of core. Relative oil permeability data in the water-oil-gas systems are presented, and it is shown that if the water is considered part of the rock matrix, the relative oil permeability curve is typical of a wetting phase relative permeability curve. Apparatus for measuring two and three phase relative permeabilities is described.

76-G
Steady Flow of Two-Phase Single-Component Fluids Through Porous Media

Frank G. Miller, U. S. Bureau of Mines, San Francisco, Calif.

Developments of fundamental equations for describing the flow and thermodynamic behavior of two-phase single-component fluids moving under steady conditions through porous media are presented. The significance of the underlying flow theory in oil-producing operations is indicated. In particular, the theoretical analysis pertains to the steady, adiabatic, macroscopically linear, two-phase flow of a single-component fluid through a horizontal column of porous medium. Laboratory experiments performed with specially designed apparatus, in which propane is used as the test fluid, substantiate the theory. The apparatus, materials and experimental procedure are described. Comparative experimental and theoretical results are presented and discussed.

77-G
A Surface Indicating Pressure, Temperature and Flow Measuring Instrument for Logging Subsurface Well Conditions

M. B. Riordan, Byron Jackson Co., Los Angeles, Calif.

This paper describes the construction, principles, and field use of a recently developed surface indicating pressure, temperature, and flow measuring instrument for logging subsurface well conditions.

78-G
Iranian Gums as Treating Agents for Drilling Fluids

George Tchillingarian, Graduate Student, University of Southern California, and **Carrol M. Beeson,** Petroleum Engineering Dept., U.S.C., Los Angeles, Calif.

A study was made of the effectiveness of the natural water-dispersible gums of Iranian origin in reducing water loss in five different types of salt-water and fresh-water muds. Tests were performed at 68°F and at 180°F, and included determinations of water loss, viscosity, gel properties, and foaminess. It was found that the addition of gums improved markedly the filtration characteristics of all of the muds tested, including high *pH* red lime-base mud. Increasing the temperature from 68°F to 180°F increased the effectiveness of gum shiras and, to a lesser extent, of locust bean seed, showing them to be very valuable treating agents. The results of the investigation indicated that Iranian gums would prove extremely useful in drilling in the salt-dome area of the Near East and in other parts of the world.

EXHIBITORS IN NEW ORLEANS . . .

LARKIN & CO., INC. (Booth 3) — Will feature packers for secondary recovery. Working models of flood packers, balloon packers, equalizing pressure packers, upside down pressure packers, as well as other production and formation types. Will also feature Larkin "Packerlog" service.

HALLIBURTON OIL WELL CEMENTING CO. (Booth 1) — Cut-away models of Halliburton service and sales tools. Will feature new Electrical Side Wall Coring Tool along with their Caliper Tool. Also Formation Testing Tool and the BT Bomb Pressure Recording Device. Floating Equipment and allied tools.

EASTMAN OIL WELL SURVEY CO. (Booth 4) — Background showing an oil well bore hole that is directionally drilled under a salt dome. Also a diagram showing the applications of directional drilling. Equipment to include Eastman Single Shot, Type W Mechanical Drift Indicator and other instruments.

CORE LABORATORIES, INC. (Booth Adjoining Stair) — (A) Technical display with photographic blowups of derrick-side Well Logging units showing exterior and interior views of equipment in use. On-location core analysis, off-location core analysis and others. Also Reservoir Fluid Analysis. (B) Coffee bar serving refreshments free.

KEYSTONE DEVELOPMENT CORP. (Booth 14) — The Sonolog Acoustic Well Sounder, widely used in "problem" wells. Also will feature their High Pressure Well Head Attachment for use on high pressure condensate wells. This special attachment is used with the regular Sonolog recorder.

GROVE REGULATOR CO. (Booth 17) — Will exhibit the Versatile Flexflo Expansible Tube Valve, the Chexflo Check Valve used in meter runs, disposal lines and other services. Also will show the Grove Powreactor Dome Regulator, the Grove Seat-Seal Valves and the Grove Models "S" and "SL" Valves.

DOWELL INCORPORATED (Booth 8) — Will consist of materials and pictures explaining the Dowell services. Emphasis will be placed on Gulf Coast services. Included will be oil well plastics. Actual well cores of sands before and after Dowell Sand Consolidation Plastics are used will be shown. Also mud acid.

LANE-WELLS CO. (Booth 10) — Gun perforating, Knewshot perforating, radioactivity packer and bridging plug displays will be shown. The Magic Packer display will also be presented. It is suspended in air with no apparent means of support.

SHAFFER TOOL WORKS (Booth 2) — Will present engineering data on the Shaffer Hydraulic Cellar Control Gate, show models of the Shaffer-Waggener Bumper Safety Joint, the Shaffer Jar Safety Joint and the Shaffer Blowout Preventer.

BAKER OIL TOOLS, INC. (Booth 9) — Will exhibit Baker Model "RT-8" Retrievable Cementer, "K" Cement Retainer, "D" Retainer Production Packer, "C" Rotary Casing Scraper, Cement Wash Down Whirler Float Shoe, Cement Float Collar, and Wire Line Bridge Plug.

B & W INCORPORATED (Booth 16) — Displays of B & W scratcher, centralizer and gravel packing equipment. Booth will be dominated by photographs and a small gravel packing model.

GEOPHYSICAL RESEARCH CORP. (Booth 7) — Will show the Amerada Bottom Hole Recording Pressure and Temperature Gauge. A working cut-away model will be on display together with all parts that go into this instrument. Petroleum engineer and a gauge maintenance engineer will be on hand to answer questions.

SCHLUMBERGER WELL SURVEYING CORP. (Booth 18) — A working scale model of the MicroLog comprised of the basic essentials. Formations will be simulated along with mud cake and drilling fluid. The MicroLogging tool will be scaled down to fit the model operated manually under glass. Also a full scale MicroLogging tool of newest type.

JOHNSTON OIL FIELD SERVICE CORP. (Booth 12-13) — Will display plexiglass mechanical models of testing equipment featuring the Shut-in Pressure Reverse Circulating Valve. Equipment for both open hole testing and production testing inside casing will be available for examination.

GEO. W. FAILING SUPPLY CO. (Booth 11) — Exhibiting late model products and equipment.

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MARTIN-DECKER CORP. (Booth 6) — Will exhibit for the first time their Type F indicating and recording weight instrument, the Hydro Mech indicating and recording instrument, the Tong Torque Indicator and the Drillogger.

HOUSTON OIL FIELD MATERIAL CO., INC. (Booth 8) — Exhibit will contain scale models of the Homco Releasing Overshot, Releasing Spear, Inside and Outside Pipe Cutters, Drilling Type Safety Joint, Tubing Safety Joint, Hexagonal Bumper Jar, Safety Lock Lifting Plug and Directional Drilling Tools. Also subsurface survey instruments with cut-away models.

McCULLOUGH TOOL CO. (Booth 16) — Oil well tools on display will include electric wire line tools, rotary tools and surface equipment. The latter will feature an electrical control panel, electronic weight indicator and sonic device, the "brain" and "nerve system" of all McCullough electric wire line operations. Demonstrations will be given.

THE RAPID BLUE PRINT CO. (Booth 18) — Will give away sets of four different works of calendar art (without the calendar). Will also serve free soft drinks.

BAKER OIL TOOLS, INC. (Booth 5) — Will display the Baker Model "G" Casing Scraper, Product No. 910-G. Also an operating model of simulated Baker Wash-Down Whirler Float Shoe, Product No. 120. Cut-away models of Baker Model "D" Retainer Production Packer, "K" Retainer Bridge Plug, "K" Cement Retainer, "C" Open Hole Bridge Plug.

HALLIBURTON OIL WELL CEMENTING CO. (Booth 7) — Will exhibit their Formation Testing Tool and the BT Bomb Pressure Recording Device, Floating Equipment and allied tools. Will have a minor display of standard measuring devices and accessories. All tools will be cut-away models.

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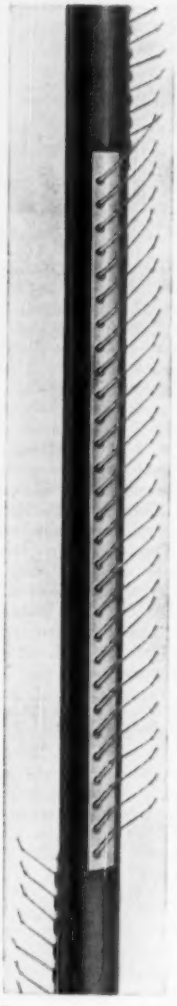

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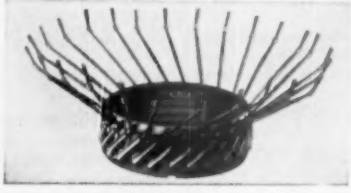

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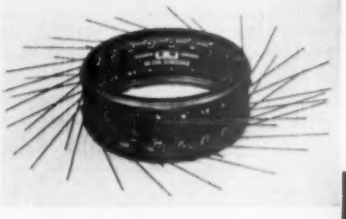

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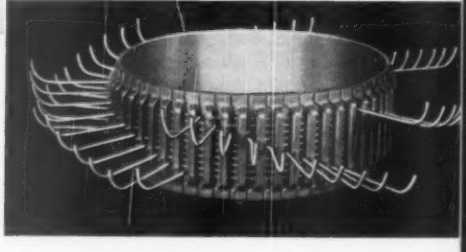

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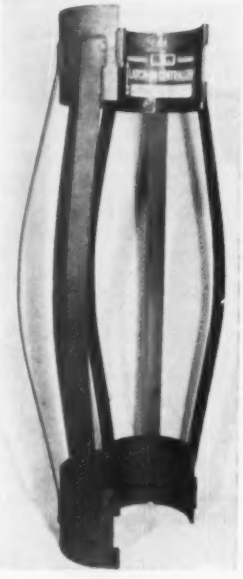

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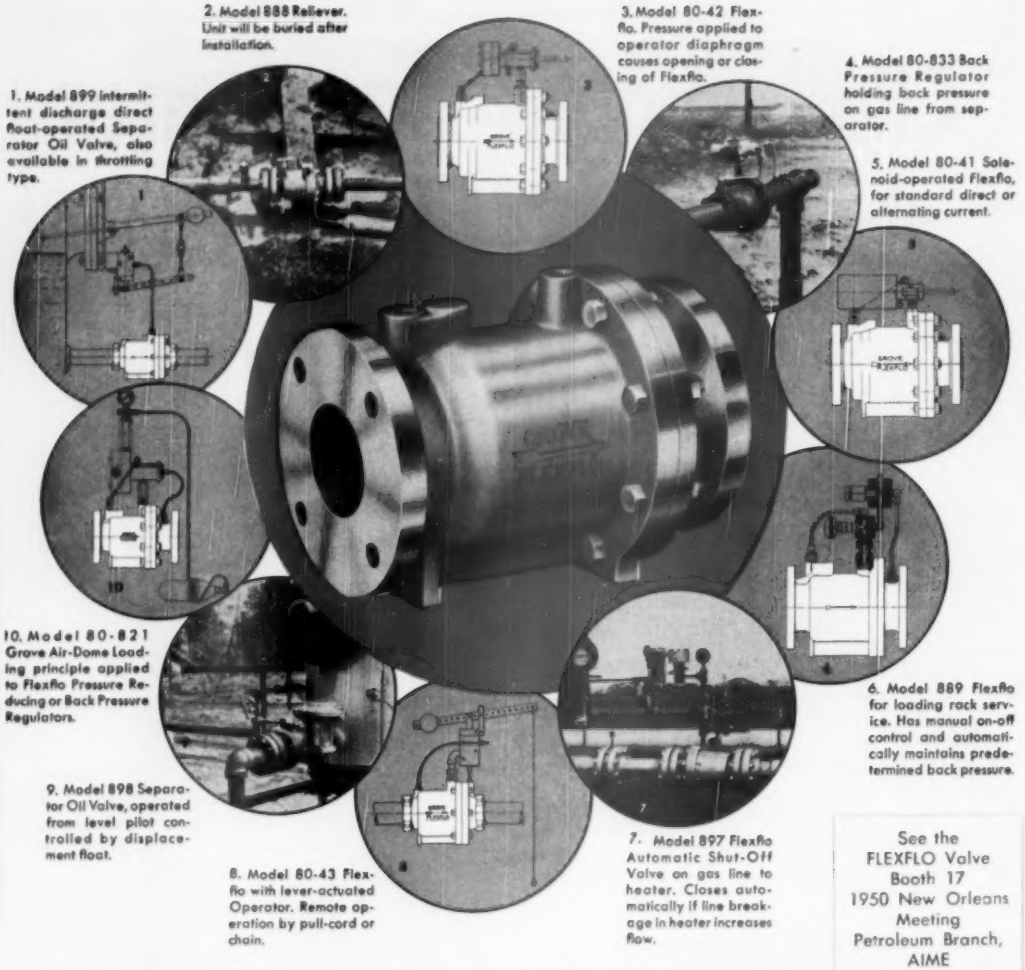

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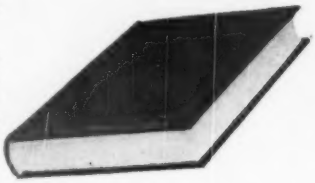

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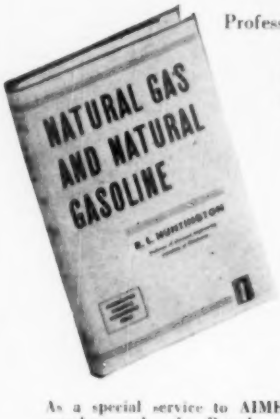

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A STUDY OF RESERVOIR PERFORMANCE OF THE FIRST GRUBB POOL, SAN MIGUELITO FIELD, VENTURA COUNTY, CALIFORNIA

WAYNE E. GLENN, CONTINENTAL OIL CO., LOS ANGELES, CALIF., MEMBER AIME

ABSTRACT

The San Miguelito Field of Ventura County, California, lies along the coast approximately five miles northwest of the city of Ventura. The structure is one of several in the Ventura anticline, a series of anticlinal folds trending northwest-southeast through the San Miguelito Field. The Ventura Avenue Field lies to the southeast along the anticline, and Padre Canyon and Rincon Fields lie to the northwest; the series then extends beneath the Pacific Ocean. Production is obtained from the Lower Pico and Repetto formations of Pliocene age, and oil accumulation is controlled by faulting, lithology and structure. The first well in the First Grubb Pool was completed in November, 1931, and to date 48 producing wells have been drilled on the 276 productive acres. Approximately 685 ft of net pay are contained in the eight sand bodies grossing 1,220 ft of section. Production of oil to date has been 15,600,000 bbl. A gas injection project was instigated in April, 1940, but was discontinued in September, 1949.

This paper is confined to a discussion of the development and performance history of the First Grubb Pool of the San Miguelito Field.

LOCATION AND GEOLOGY

The San Miguelito Oil Field is located in Ventura County about five miles northwest of the city of Ventura along the coastal highway to Santa Barbara. It is located within sections 23, 24, 25, and 30 of Township 3 North, Range 24 West, San Bernardino Base and Meridian. Surface elevation in the field ranges from sea level to plus 1,200 ft, and the terrain is extremely rugged. The structure is well defined on the surface and on the wall of the Amphitheatre Canyon where appears a so-called "text book" anticlinal section.

The San Miguelito structure is an asymmetrical, elongated anticline about two miles long and three-fourths of a mile wide. The trend of the axis of the anticline is northwest-southeast. Fig. 9 illustrates the contours and major faults of this structure. Dips on the southwesterly flank average about 40 degrees, whereas the northeasterly flank ranges from 60 to 75 degrees. There are several faults striking generally east and west. These faults do not appear to affect materially the area of accumulation or performance behavior. It is believed that accumulation was affected by steeply dipping beds and extremely low permeability of the northeast flank of the structure.

As shown by the typical log, Fig. 1, the San Miguelito Field is divided into two stratigraphic producing intervals. The First Grubb Pool comprises the interval from the "G" to "L" markers; the Second Grubb Pool from the "L" to "M" markers. The First Grubb Pool, ranging in thickness from 1,105 to 1,680 ft, with an average of 1,220 ft, includes approximately 685 ft of oil-bearing sands. The First Grubb zone consists of eight sand intervals separated by shales.

The shale bodies separating the eight sand intervals within the First Grubb Pool are continuous throughout the major part of the structure and serve as an effective barrier. Many of the thin, irregular shale or siltstone streaks within these sand bodies are discontinuous and do not affect well performance appreciably.

The productive horizons in the First Grubb Pool are siltstones and sandstones of the Lower Pico and Repetto formations of Pliocene age.

It is apparent from inspection of the typical log that the "G" to "L" interval might have been separated into at least six producing zones and selectively produced. Unfortunately the electric log and some of our modern tools were not available or were in their infancy during the period 1931 through 1937. Not until 1937 when eight wells had been completed were there sufficient geological data to permit definition of the sand bodies. Then the problem of reservoir control in this multiple-sand field, where all sands are open to a common

[1]References given at end of paper.
Manuscript received at the office of the Petroleum Branch October 26, 1949. Paper presented at the Petroleum Branch meetings at San Antonio, October 5-7, 1949, and at Los Angeles, October 20-21, 1949.

Table I

Summary of Formation Characteristics

Sand Interval	Weighted Average Perm. md	Weighted Average Porosity Per Cent	Average Strat. Thickness, Ft	Average Net Effective Pay, Ft	Acres Within Productive Limit
G - H	237	17.2	100	71.3	97
H - Ha	79	18.1	125	77.5	148
Ha - I	71	17.2	130	75.2	180.5
I - Ia	56.6	19.5	115	65.4	158.3
Ia - J	47.8	17.9	140	70	258
J - Ja	109	18.5	125	82.7	262
Ja - Jc	107	19.2	215	111.1	165.3
Jc - K	56	17	240	131.3	276
K - L	36.2	17.6			
Pool	86	18	1220	685	1545

well bore, was recognized. Because of the number of wells completed, cost considerations, and the complexity of the structure, however, the decision was made to produce all oil-bearing sands simultaneously. Fig. 2, typical sections, illustrates the complex geologic problem that accounts to a large extent for this type completion and for the slow development rate.

The First Grubb Pool of the San Miguelito Field was discovered with completion of Grubb Well No. 1 in November, 1931, at a depth of 6,750 ft for an initial potential of 616 B/D of 32-degree API gravity. In August, 1932, it was recompleted with an initial production of 2,449 B/D. As of September 1, 1949, 48 producible wells had been drilled to the first Grubb horizon.

FORMATION AND FLUID CHARACTERISTICS

The reservoir rocks are quite typical of California Pliocene sands. They are generally rather poorly sorted and contain a large amount of silty argillaceous material, ranging from firm well consolidated sands of low permeability to unconsolidated highly permeable sands, as shown by the typical log and as summarized in Table I.

Porosity and permeability determinations are somewhat limited as only some 800 samples from 20 wells were analyzed. The weighted average porosity is 18 per cent, and the average permeability is 86 millidarcies. The pool weighted average porosity and permeability were determined by arriving at an average value for each foot of sand, measured from the top of each sand marker. These average values were then applied to the corresponding sand interval of each well penetrating the First Grubb Pool.

The permeability variation is extremely high, but there does seem to be some correlation between wells. Based on the information available, it is estimated that 27 per cent of the average pore space is occupied by water.

In contrast to the typical California reservoir, the sand intervals increase in areal extent with depth; that is, the "G" to "H" interval contains a productive area of 97 acres while the "Jc" to "L" interval contains 276 acres. Permeability generally decreases with depth except for the "Ja" to "Jc" interval which is comprised of a "coarse pebble bed." The productive limits are in general defined by the Padre fault and permeability on the north, faulting and permeability on the east, water on the south, and permeability on the west flank. The productive limit along the southwest flank, as defined by water-oil contact, is very irregular as would be expected in a reservoir of this type. Faulting and permeability are the controlling factors. The Isopachous maps, Figs. 3 through 3c, indicate the relative sand volume and productive limits of each sand interval. The average gross sand thickness is 1,220 ft, whereas the net effective thickness averages about 685 ft. (The well numbers followed by "-2" indicate Second Grubb Pool wells.) The total bulk sand volume of the First Grubb Pool was calculated to be 136,600-acre ft. The essential formation characteristics are shown in Table I.

As there was but one rather poor analysis of a bottom hole fluid sample taken in 1940 at a static pressure of 2,700 psig, reservoir fluid characteristics were recalculated. The recalculation was based on reservoir performance, published papers, and early stage separation work. The original saturation pressure is estimated to be 3,000 psig

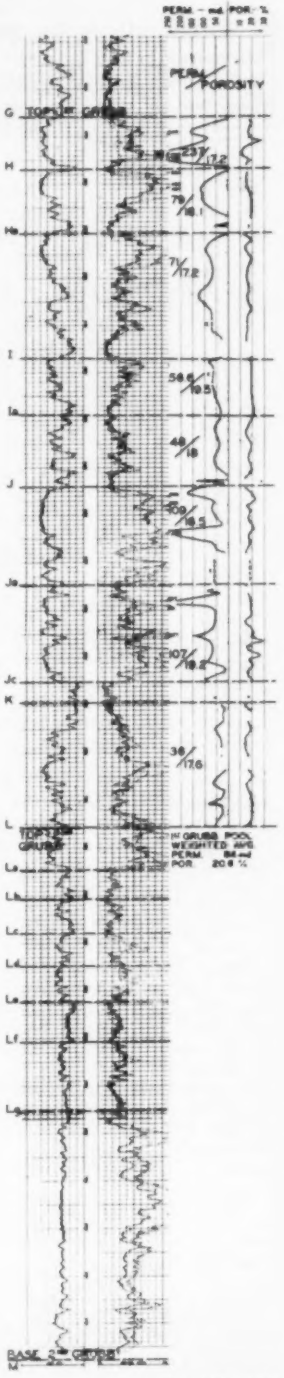


FIG. 1 — TYPICAL LOG.

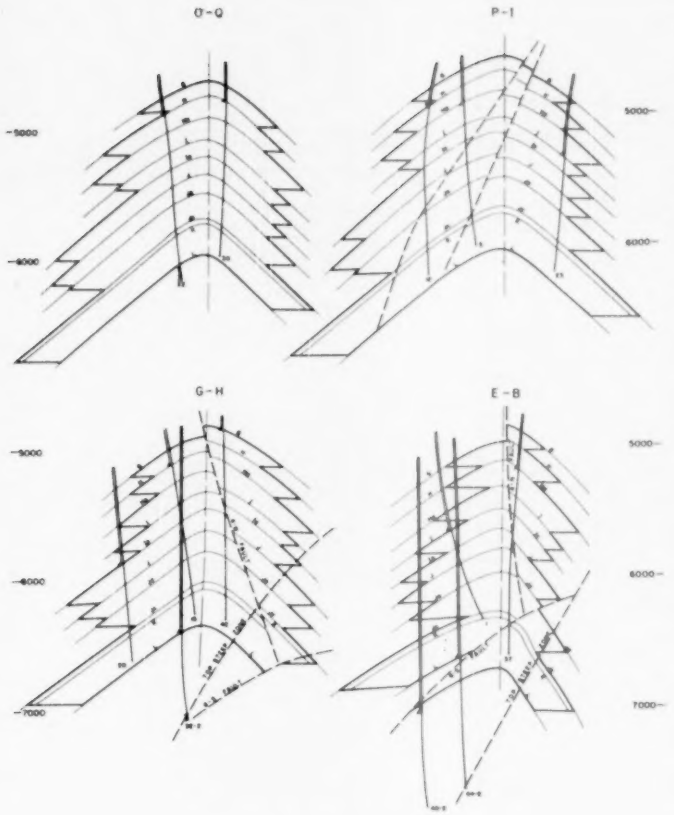


FIG. 2 — TYPICAL SECTIONS.

at the −5,500 ft field datum and 158°F. Subsurface sample data were extrapolated to these conditions, and a formation volume factor of 1.428 bbl per bbl was used to correct reservoir volumes to stock tank conditions.

The viscosity of the oil at subsurface temperatures of 158° and 3,000 psig was 0.92C_p. The produced oil gravity was 32 degrees API at 60°F. This gravity varies with trap pressure and temperature. The solution gas-oil ratio was calculated to be 890 cu ft per bbl. With the exception of three wells near the axis of the structure and considering trap pressure, the original produced gas-oil ratios verify this figure.

Average original pressures were calculated by zones using the water gradient through each oil saturated interval from top to bottom. This procedure was justified due to the fact that water existed at the productive limit of each zone. The temperature of each oil saturated interval was measured by means of a recording thermometer. The pressure and temperature gradients under estimated original conditions are shown in Fig. 4.

Original tank oil contained in each sand interval was determined by using fluid data shown in Table II. Using the pore volume, mean temperature and pressure (Fig. 4 and Table III), and the reservoir fluid characteristics as determined, the original tank oil in place was calculated for each of the eight sand intervals. In the remainder of the calculations, the reservoir was treated as a single producing unit, it being impossible to determine the performance of individual zones since all were open to a common well bore.

RESERVOIR PERFORMANCE

Production statistics of the pool are unusually complete and accurate. Individual well oil, gas, and water measurements have been recorded since inception. These data plus frequent reservoir pressure and P.I. surveys make individual well and reservoir performance studies more reliable than is often the case in a field of this age.

A record of reservoir performance is shown by Fig. 5. To illustrate the individual well performance, which is often more indicative of true reservoir performance than is the pool curve, Figs. 6 and 6a are included. These figures show the performance history of individual wells. Correlation of well and pool behavior, as to spread of high gas-oil ratios, water production, gas-oil segregation and gas channeling, with the cumulative oil production and gas injection map shown by Fig. 7, yields a panorama of the extent to which gas-oil segregation is achieved.

Pool performance history is characterized by effects of concentrated development, localized withdrawal at high rates, gas channeling, and gas-oil segregation. The magnitude of these effects is obscured in Fig. 5 by selective well production in later years. Recent well completions of down-structure wells and selective reservoir control have resulted in the lowering of pool gas-oil ratios as reflected by Figs. 5 and 8. A study of individual well behavior in conjunction with structural position, penetration, subsurface pressure characteristics, P.I., and gas-oil ratio histories discloses a typical low permeability, solution gas drive pool. Water encroachment in thin, high permeability sands in the "I" and "J" intervals and gravity drainage are now affecting well and reservoir performance.

While gas-oil ratios vary to some degree with oil rates in the high-structure wells where there exist zones of low liquid saturation, this is not believed to be the case in the early stages of development, nor is it true now in low-structure wells where liquid saturation is high.

The declining oil production rates, as shown by Fig. 5, reflect the reduction imposed by MER adjustments rather than the actual decline in producing capacity of the wells. This fact is borne out by the completion of 20 wells since the peak production year, several of which had potentials in excess of 1,200 B/D.

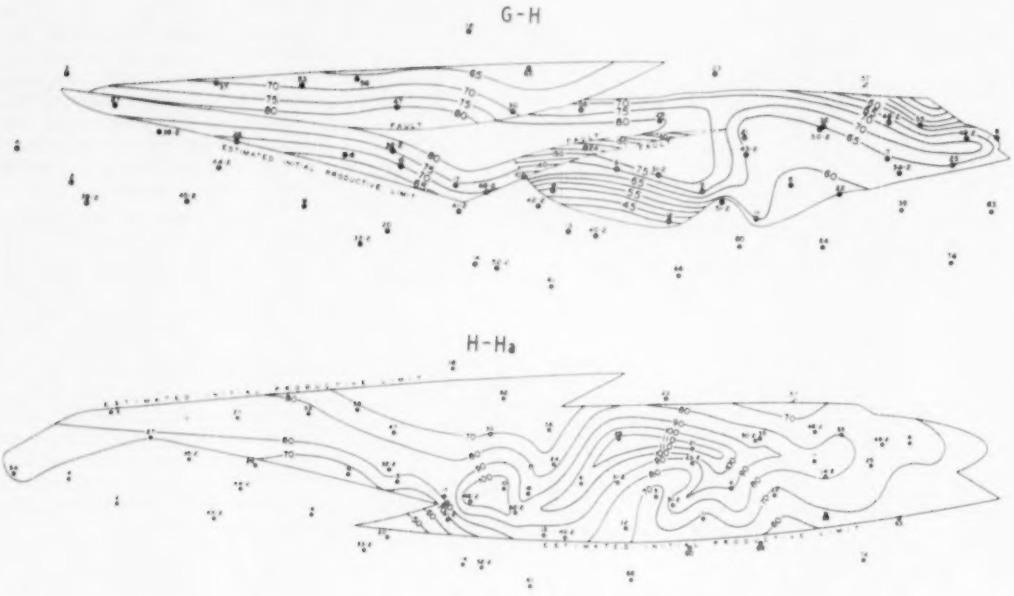


FIG. 3 — ISOPACH MAP — G-H AND H-Ha SECTIONS.

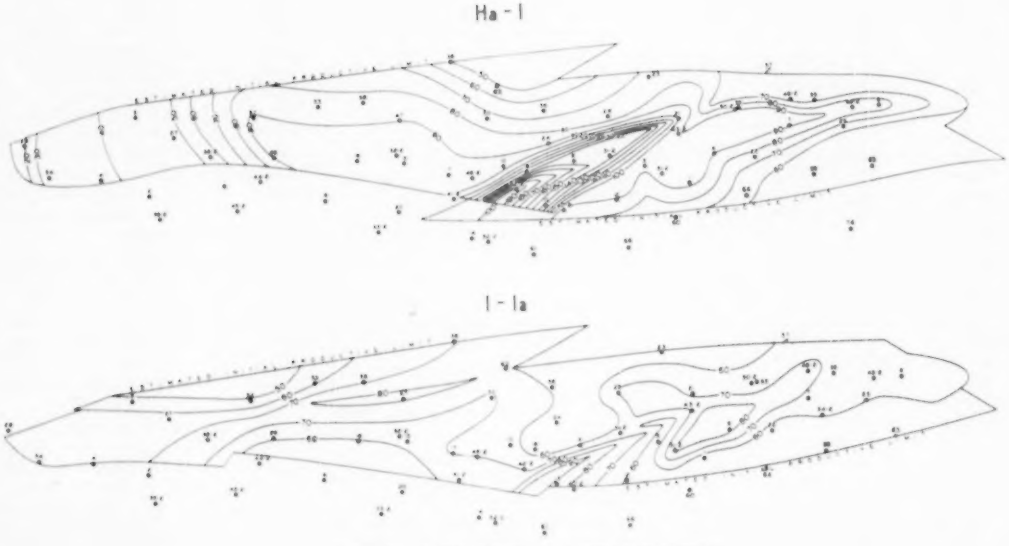


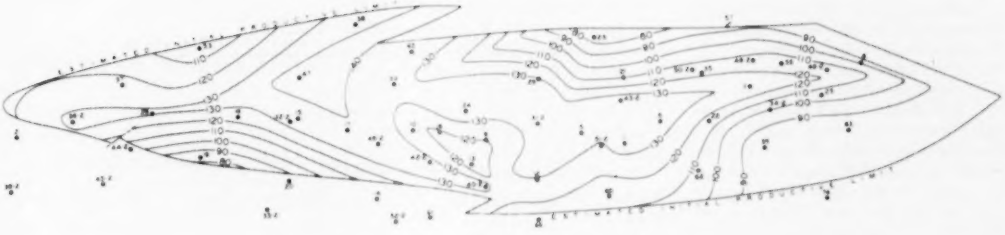
FIG. 3a — ISOPACH MAP — Ha-I AND I-Ia SECTIONS.

Ia - J

J - Ja

FIG. 3b — ISOPACH MAP — Ia-J AND J-Ja SECTIONS.

Ja - Jc



Jc - L

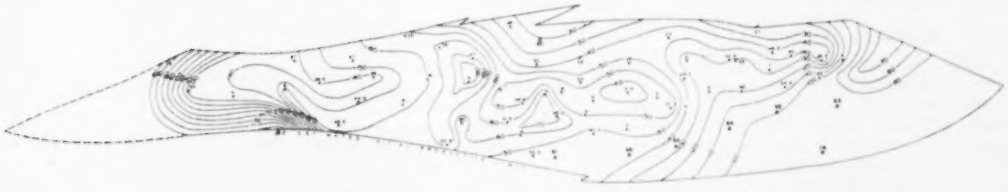


FIG. 3c — ISOPACH MAP — Ja-Jc AND Jc-L SECTIONS.

Table II
P.V.T. Data

Sand Interval	Original Mean Sand Interval Pressure	Original Mean Sand Interval Temp.	Formation Volume of Saturated Oil B/B.S.T.O.	Saturation GOR
G - H	2770	149	1.406	830
H - Ha	2817	151	1.410	840
Ha - I	2875	154	1.416	852
I - Ia	2930	157	1.422	866
Ia - J	2985	159	1.427	875
J - Ja	3042	162	1.433	888
Ja - Jc	3105	165	1.438	898
Jc - K	3195	169	1.448	915
Pool Datum	3000	158	1.428	890

Throughout 1943, the pool production rate increased with development to reach a maximum daily oil rate of 5,500 bbl. During the period from early 1944 through 1947, only an average of 1.3 wells per year were completed in the First Grubb Pool. To permit control of withdrawal and to develop the productive sands that would not be adequately drained otherwise, the development rate was increased during the period 1947 through 1949 by completion of 15 wells. With the completion of four additional wells in 1950, development will be complete.

The high production rate of well No. 5 for approximately 18 months after completion created a low-pressure area, the effects of which have been erased by pressure depletion only in the past two years.

Gravity drainage has been effective in maintaining a high oil saturation in the down flank wells as evidenced by the gas-oil ratio performance of the individual wells. The effectiveness has been minimized by high up-dip differential pressures until very recently. It is practically impossible to calculate the amount of gravity drainage taking place in a field of this type where several sand intervals are open to the same well bore. A recent 46-day shutdown of the field gave strong indication of gravitational migration of the oil and gas, as noted from declines in gas-oil ratios of down-structure wells.

GAS-OIL RATIO

Initial produced gas-oil ratios (Fig. 9) were equivalent to the solution ratio in those early wells in which the "H" marker is located below −4,800 ft elevation. The variation in value as reported is due largely to gas remaining in solution at separation pressure.

The abrupt rise of the pool gas-oil ratio during 1936 and 1937 coincides with the completion of Grubb Well No. 5, which had an initial gas-oil ratio of 5,500 cu ft per bbl, six times the solution ratio of 890, and the completion of Well No. 7, which initially produced 9,561 cu ft of gas per bbl of oil. Gas-oil ratios of both of these wells declined with dissipation of a small gas cap in the thin gas sands located in the "Ia" and "J" interval near the axis of the structure so that by 1940 the ratios of these two wells compared with the pool ratio of 1,250 cu ft per bbl. It is significant that Grubb Well No. 1, while produced at rates equivalent to Well No. 5 had produced approximately 1,530,000 bbl of oil before the gas-oil ratio exceeded 1,300 cu ft per bbl. The comparative performance of the two wells is shown in Figs. 6 and 6a. Several original small stray gas sands occurred above the −4,800 ft contour; and although the free gas was rapidly dissipated, wells completed as late as 1941

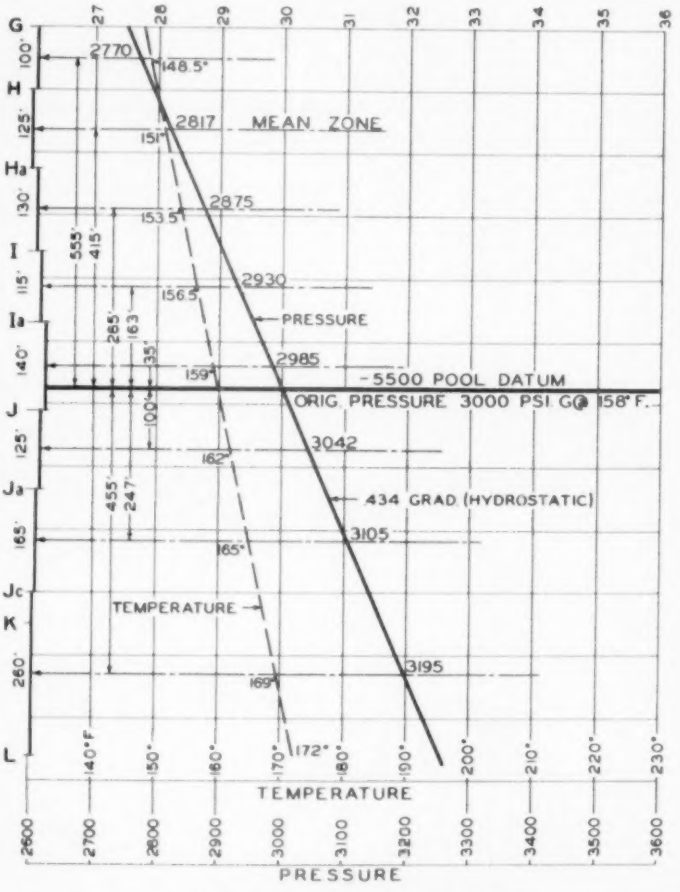


FIG. 4 — PRESSURE AND TEMPERATURE CHART.

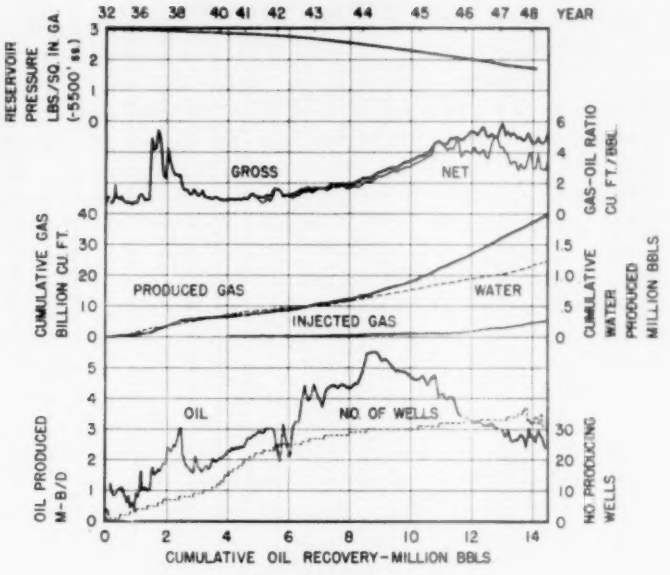


FIG. 5 — RESERVOIR PERFORMANCE

produced free gas, as indicated by the initial ratio of Well No. 21. This well's initial ratio of 5,892 cu ft per bbl declined to near normal by 1943. Well No. 8 demonstrated similar characteristics although located across the 3N fault.

The high initial ratio of Well No. 27 reflects gas injection in the upper part of the "I" to "Ia" interval in Well No. 3. These wells are not separated by the 4N fault, as the fault intersects both wells above the "H" marker.

In general, the gas-oil ratio trend maps, Figs. 10, 10a, and 10b, illustrate effective gas-oil segregation, localized gas channeling, and the effects of high withdrawal rates.

The upward trend of the pool gas-oil ratio during the war years reflects the effect of heavy withdrawals from structurally high wells which caused local areas of low liquid saturation and low pressure. Gas injection initiated in 1940 adversely affected the gas-oil ratio due to channeling of the injected gas. The reversal of the pool gas-oil ratio trend in 1946 was due to the completion of low gas-oil ratio wells downstructure and shutting in high ratio wells.

Until excess gas is excluded in the "intermediate" and "high" ratio group wells, maximum withdrawal should be obtained from the current low ratio and newly completed wells. The exclusion might be accomplished by selectively plugging gas sands or changing injection intervals. When this work is successfully completed, all wells will be selectively produced.

Even though gas channeling, permeability distribution, and method of operation may affect recovery, it is well to remember that the cumulative ratio is an index to ultimate recovery, not considering gravity drainage. Ratio control in a reservoir of this type is difficult because of the fluid and reservoir characteristics, stage of depletion of some sands, and inter-communication between sand intervals within the First Grubb Pool.

GAS INJECTION

The First Grubb reservoir is primarily a solution-gas-drive and gravity drainage type; therefore, operating procedure is based on the performance of that type of reservoir. A small-scale gas-injection project was initiated in April, 1940, as a conservation measure and to determine the feasibility of augmenting the natural reservoir energy and sweeping the oil sands with injected gas, thereby increasing the ultimate recovery of oil. The relatively small volume of gas injected to date has not affected over-all reservoir mechanics other than to serve as a gas sweep through a very limited sand volume. Gas channeling has minimized the effectiveness of gas injection. The initial gas-injection well, Grubb Well No. 3, is located on the north flank of the structure in the western part of the field. The injection intervals were "H" to "Ha," "Ha" to "I," and "I" to "Ia," comprising about 180 ft of effective oil sand. During 1941 and 1942, the daily average of 0.450 MMcf of gas was injected at a well head pressure 3,200 psi. This volume was increased to 0.75 MMcf daily during 1943. By November, 1943, a total volume of 511 MMcf of gas had been injected. At this time gas injection in Well No. 3 was discontinued because of gas channeling evident in Grubb Well No. 27. This well was completed in September, 1942, offsetting the injection well, with an average gas-oil ratio of 2,285 cu ft of gas per bbl of oil. Considering the low effective permeability of the sands open to production in this well, the low initial productivity index, the abnormally high pressure, and a gas-oil ratio three times solution ratio which increased 600 cu ft per bbl within a month, it became evi-

Table III

Pressure and P. I.

Year	Field Datum -5,500 Weighted Areally Surface-Acres	Well Datum Weighted by Bulk Vol. in Drainage Area	Number of Wells in Survey	Prod. Index Range
Original	3,000	3,160		
July, 1938	2,954	2,934	8	1.40-2.25
June, 1939	2,914	2,890	10	.07- .76
December, 1940	2,877	2,808	19	.70-4.16
December, 1941	2,847	2,759	23	.15-3.19
December, 1942	2,742	2,626	27	.13-1.80
December, 1943	2,566	2,438	29	.04-1.54
November, 1944	2,323	2,156	30	.14-1.80
August, 1945	2,129	1,939	32	.09-1.14
September, 1946	1,956	1,783	33	.04-1.04
March, 1947	1,830	1,640	34	.08- .96
March, 1948	1,745	1,547	38	.08-1.04

dent gas injection into Well No. 3 was channeling through highly permeable streaks and adversely affecting Well No. 27.

After again placing Well No. 3 on production, a total of 25,565 Mcf gas was produced at an average ratio of 3,909 cu ft per bbl with a pressure drawdown of approximately 1,100 psig before a normal producing ratio was reached. This indicates the very small volume of gas that was stored in the reservoir in a period of three years.

Well No. 24 was converted to injection in November, 1943. The initial daily injection rate was approximately 1,600 Mcf. Upon addition of compressors in 1945, the daily rate was increased to 5,000 Mcf, which rate has been maintained. From 1943 until September, 1946, approximately 2,000,000 Mcf of gas was injected into Well No. 24 with the sand interval from "H" through "K plus 190" ft open. The high permeability, high gas-saturated sands from "Ia" to "Jb" were receiving the injected gas. The K_g/K_o relation in these thin sands resulted in by-passing the remaining liquid saturation. A review of gas-oil ratio and performance trends of individual wells led to an attempt in November, 1946, to inject gas selectively into the "K plus 190" ft sand interval. The blanks between each sand interval were squeezed prior to setting a packer in the blank liner opposite the "Jc" to "K" shale. After injecting 2,600,000 Mcf of gas in this interval, a review of well performance was made in order to determine future injection policy. The study revealed gas entry into two thin permeable streaks within the "K" to "L" interval. This gas migration is shown on the temperature and flow meter survey chart, Fig. 11. After a review of these data, the injection interval in Well No. 24 was changed from the "K" to "L" to the "Jb" to "Jc" interval. The "K" to "L" interval was plugged with a temporary bridge plug. To date this has proved an effective means of controlling gas channeling within zones. Well Nos. 5, 6, and 12 and other high-structure wells have shown a marked decrease in gas-oil ratio. Several flowing wells have required artificial lift equipment since changing this injection interval. Subsequent flow meter surveys and temperature surveys have clearly indicated a rapid decrease in gas channeling, and the character of these surveys has changed appreciably.

Gas injection has affected all high-structure wells above −4,850 ft, Well No. 13 at −5,025 ft, and Well Nos. 15 and 17 at an elevation of −5,080 ft.

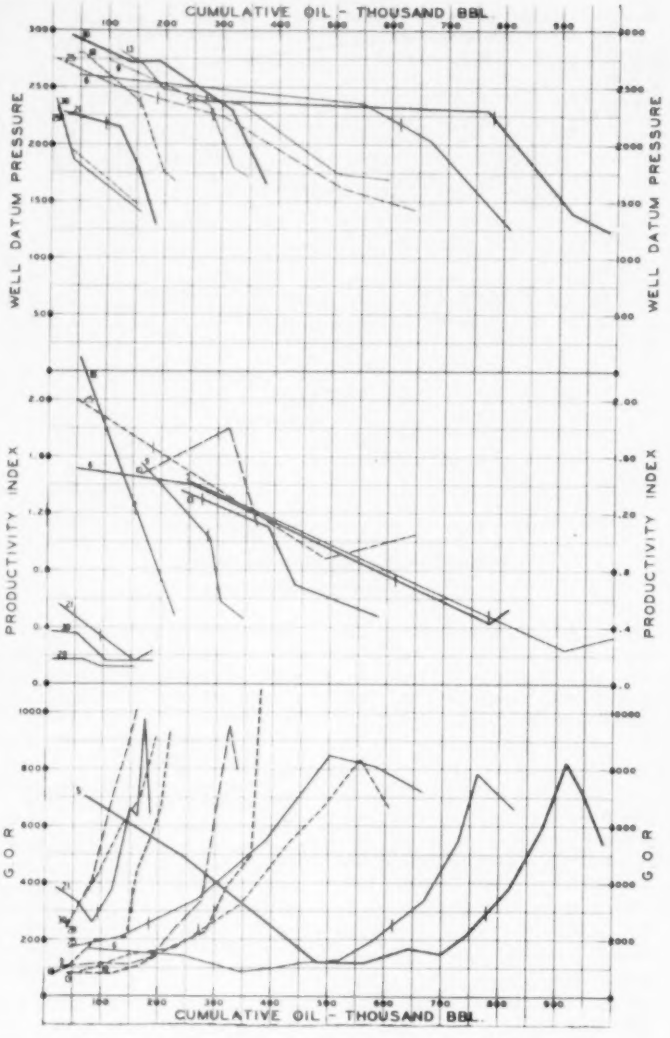


FIG. 6 — P.I., G.O.R., PRESSURE VS. RECOVERY — HIGH GAS-OIL RATIO WELLS.

Performance trends of significant wells, grouped as to gas-oil ratio, are shown by Figs. 6 and 6a. The gas-oil ratio curves of Well Nos. 9, 10, and 18 indicate channeling within one to three months after injection started in Well No. 24. The second change in Well Nos. 10 and 18 occurred in September, 1945, the month the injection rate was increased to 5,000 Mcf per day. Well No. 6 produced 56,000 bbl while Well No. 5 recovered only 41,000 bbl of oil before gas-oil ratio trends reflected gas injection. Productivity indices increase with a corresponding decrease in gas-oil ratio of the high ratio wells. This is not true in the low ratio group of wells. The low-structure wells are not adversely affected by gas injection; therefore the gas-oil ratios remained relatively low due to gravity segregation and to some extent gravity drainage.

To date about 7,000,000 Mcf of dry

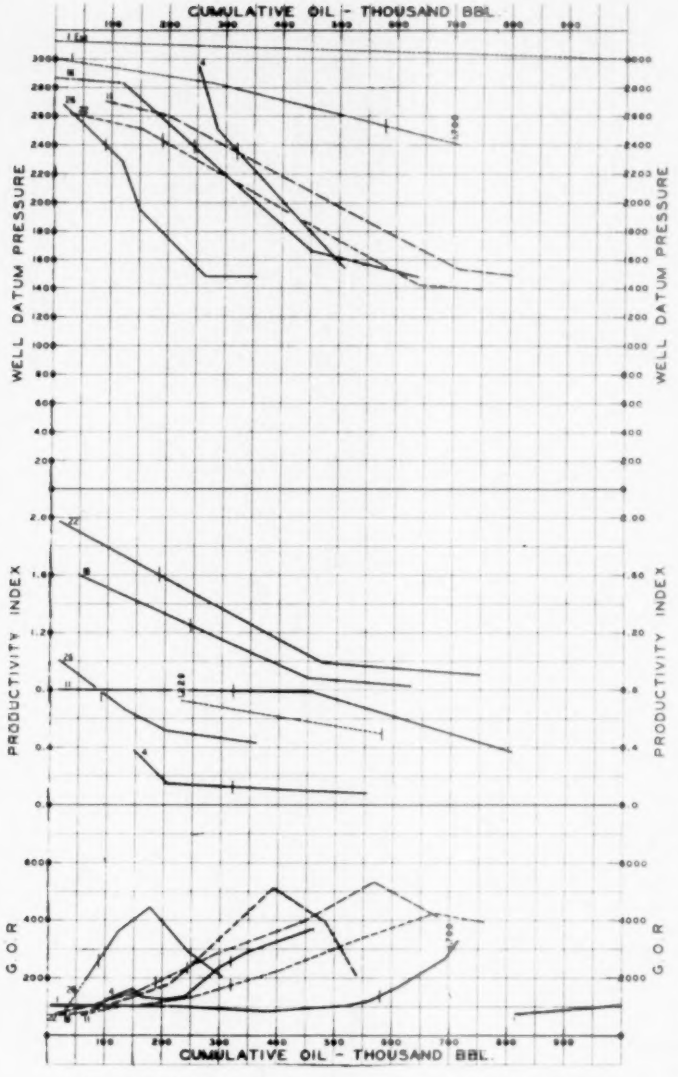


FIG. 6a — P.I., G.O.R., PRESSURE VS. RECOVERY — LOW GAS-OIL RATIO WELLS.

gas has been returned to the First Grubb Pool. This represents about 15 per cent of the wet gas produced. Gas injection in the First Grubb Pool was never intended solely as a pressure maintenance project. It was for the purpose of gas storage, to prolong the flowing life of wells, to determine the feasibility of gas sweep to increase oil recovery, and to some degree to retard pressure decline. This project was successful only in prolonging flowing life of wells and as a guide to future injection methods. Selective low-pressure gas injection is proposed, which is more favorable and more easily controlled in a reservoir of this type.

The total volume of gas injected into the First Grubb Pool is by no means sufficient to arrive at a conclusive answer as to what full-scale pressure maintenance might have done; however, it is hard to conceive how reservoir performance and ratio control could have been greatly different from that which has been experienced by injection in Well No. 24. It does not seem feasible that high-pressure gas injection into an interval of this thickness could be controlled. There are two definite schools of thought as to the type gas injection project that is most efficient and economical. Some factors favor injection of gas at high pressure, while other factors favor injection at low pressure. Unfortunately, there are no general rules to follow. Any program is thusly compromised to meet optimum economic considerations while still striving to obtain maximum oil recovery.

Factors favoring maintenance of high pressure are indirect effects on oil characteristics such as high formation volume factors, low viscosity, and low surface tension by keeping gas in solution in oil. Operating benefits at high reservoir pressures include extended flowing life of wells, providing gas storage for possible use or sale, and preventing premature water encroachment. Unfortunately, gas storage and prevention of water entry is not practicable in the First Grubb Pool due to the number of zones open to a common well bore, and permeability profile. For example, if the current high gas-oil ratio wells were shut in permanently, as would be necessary under high-pressure injection, approximately 82 per cent liquid saturation would remain in this area, not considering gravity drainage. Water entry is confined to possibly two relatively thin sand zones and will require shutting off as the pool is depleted regardless of pressure.

Factors favoring injection of gas at low pressure are lower compression ratios and costs, larger displacement volume in the reservoir per surface unit of gas handled, effective utilization of the natural existing energy and agent for oil displacement (gas dissolved in oil), and greater control of fluid movement in the reservoir by selective injection and producing well control.

Since it has been demonstrated that oil is recovered primarily due to actual displacement by gas, it is necessary that the introduction of gas into the reservoir be controlled to assure that it will flow through the maximum oil-filled pore space. Herein lies an important distinction between the displacing ability of gas dissolved in oil in a reservoir and gas injected through wells. Expansion of gas released from solution provides energy and a displacing agent in each pore in which oil exists;

while injected gas, from necessity in following the line of least resistance, is capable of displacing oil from only a part of the reservoir before the ratio of gas circulation to oil recovery becomes economically prohibitive.

The part of the First Grubb reservoir which can be effectively swept by high-pressure gas, a function of permeability profile, has been determined by injection in Nos. 3 and 24. In keeping with the above, maximum recovery and ultimate economic gain should result from the injection of low-pressure gas as a sweep of each sand interval which is separated from adjacent sands by major shales.

RESERVOIR PRESSURE

First pressure observations were made in 1936 and subsequently at six-month intervals. The estimated original pressure of 3,000 p.s.i.g at −5,500 ft is based upon maximum recorded well pressures of 2,895 lb in Well No. 10 in 1939, and 2,900 lb original pressure in Well No. 14 in 1940. Other factors considered were hydrostatic head calculations, experience in similar pools of Ventura Avenue, and study of pressure recovery data.

Detailed pressure build-up time studies have been made throughout the life of the First Grubb Pool. The time required to obtain maximum build-up has varied from 12 hours in the early life of the field to more than 30 days in a recent survey. Some wells were still building up at the end of this period. A build-up curve should be obtained on every well in order to arrive at the relative "static pressure" in each well. The value of a correlation of pressure, average production rate for a period prior to the survey, and shut-in time in a low permeability reservoir of this type cannot be overemphasized.

From detailed study of the pressure history of this pool and its application to reservoir performance and material balance calculations, it was determined that two pressure values should be determined.

(1) For comparative well and reservoir performance studies to observe the effect of selective withdrawal, injection, or change in operating practices, the field datum (−5,500 ft) pressure is desirable. These values are shown on Figs. 12 through 12c and the weighted average value in Table III. The pool weighted average pressure is determined by planimetering areas between isobaric lines within the estimated productive limit of the pool.

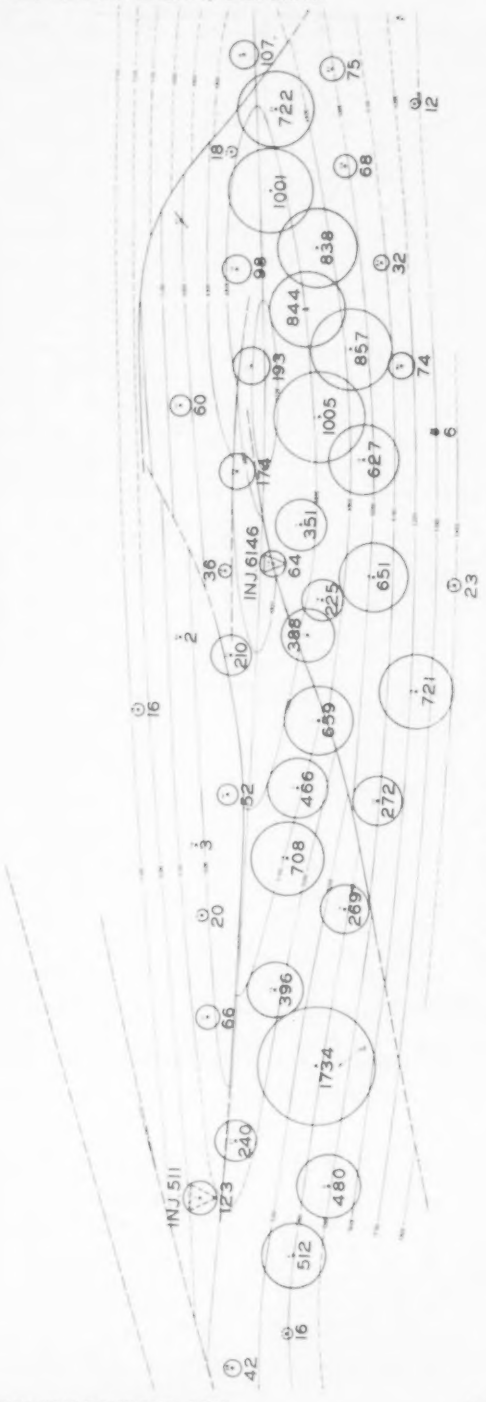


FIG. 7 — CUMULATIVE OIL RECOVERY AND GAS INJECTION — JULY 1, 1949.

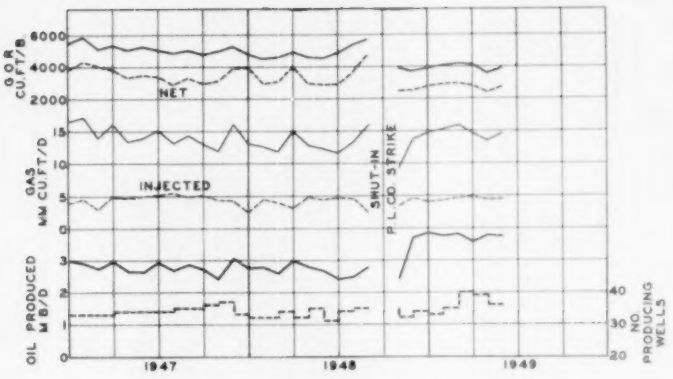


FIG. 8 — COMPARATIVE RESERVOIR PERFORMANCE.

(2) The true mean reservoir pressure is the fluid pressure at the mean depth in a whole interval, under conditions of static equilibrium. It is impractical or impossible to determine fluid distribution under static equilibrium conditions in the reservoir rock surrounding each well. Thus, a fluid gradient correction for the oil, water and gas (if gas cap exists) within the drainage area of the well bore is applied to the measured mean well datum pressure to determine the true mean pressure in the theoretical drainage area of each well. This corrected pressure is then multiplied by the net effective sand bulk volume within the wells' drainage area. The sum of these values (pressure x net acre-ft) is then divided by the total pool acre-ft to arrive at the volumetrically weighted mean reservoir pressure. This procedure was also followed in determining the pressure of the crestal, intermediate, and low structure wells (as grouped in Table IV) and in turn relative oil and gas saturation. The mean formation pressure so calculated is shown in Table III.

Reservoir pressure maps, Figs. 12 through 12e, reflect concentrated withdrawal along the southeasterly property line and subsequent pressure equalization as development progressed and withdrawals were taken more ratably. The low average permeability and permeability distribution of the north flank is evident by slow equalization and variation in pressure of offset wells. Although faults are a pressure barrier between individual sand intervals, from a reservoir standpoint faults do not alter or affect pressure performance in a pool where all zones are open to a common well bore.

Reservoir pressure decline to date is a direct function of net fluid withdrawal. Although masked by high gas-oil ratios and oil production rates since 1942, water influx has had a small effect on retarding rate of pressure decline. Since the volume and rate of water encroachment are relatively small as compared to total fluid withdrawal, it is doubtful that water will influence pool performance to any great extent until the pool nears depletion.

WELL INTERFERENCE

In spite of the heterogeneity of the producing sand, lamination of sand and shales, and faulting, there is communication between wells, as evidenced by channeling of injected gas between offset wells. The flowing characteristics of Well Nos. 9, 10, 13, and 18 are also affected by changes in production rates of nearby wells.

Gas-oil ratio and pressure maps clearly illustrate this condition. Interference between wells other than the above-mentioned is difficult to detect during the relatively short test periods involving comparatively small volumetric withdrawals.

Well No. 11 offers an excellent example of the detrimental effect of poor mud on productivity. After an initial clean-up period, the productivity index in August, 1939, was found to be 0.76 B/D per psi. This is an abnormally low value for a south flank well, as shown on Fig. 7a. The well reached its peak productivity of 1.2 B/D per psi after having produced 126,000 bbl. This characteristic is apparent in a number of the early water base mud completions.

WATER PRODUCTION

Water production during the early life of the field was of relatively minor importance. Subsequent to 1939, when several wells were drilled along the southern flank of the central and western part of structure, water encroachment through highly permeable parts of the "Ia" to "J" and "J" to "Ja" intervals was found to be sufficient to warrant expense of shut-off operations. The water front is moving along the 48 fault in a northeasterly direction. The front has reached as far into the field as Well No. 13 where the water cut increased twenty-fold since 1942. Further downstructure, in Well No. 19, the water cut has increased from 32 per cent in 1942 to 68 per cent in 1949. Total water production from the First Grubb Pool amounts to 1.3 million bbl. Five wells account for 70 per cent of the total pool water production of 370 B/D. Control of water entry has been difficult and expensive because of the long sections of slotted liner separated by 30 to 60 ft blanks set opposite shales. Water entry can be located and shut off but only at the expense of sealing off oil-productive sands of low permeability.

Table IV

Summary of Recovery Factors

	Cum. Prod. Bbl.	Acres	Ac. Ft.	B/Ac.	B/Ac. Ft.	B/Lb. Drop
GOR above 10,000	954,865	10.6	7,995	90,081	119	528
GOR 5,000 to 10,000	6,151,811	85.26	59,733	72,154	103	3,529
GOR below 5,000	7,324,234	159.94	83,253	45,794	88	5,093
Structural Elev. at top of "H" —						
above −4,800	1,603,234	38.18	21,460	41,990	75	851
−4,800 to −5,000	5,700,309	97.84	71,734	58,261	79	3,242
−5,000 to −5,500	7,041,647	112.49	54,928	62,598	128	4,596
North Flank	1,050,531	93.54	57,712	11,230	18	688
South Flank	13,445,045	169.37	98,516	90,617	136	8,022

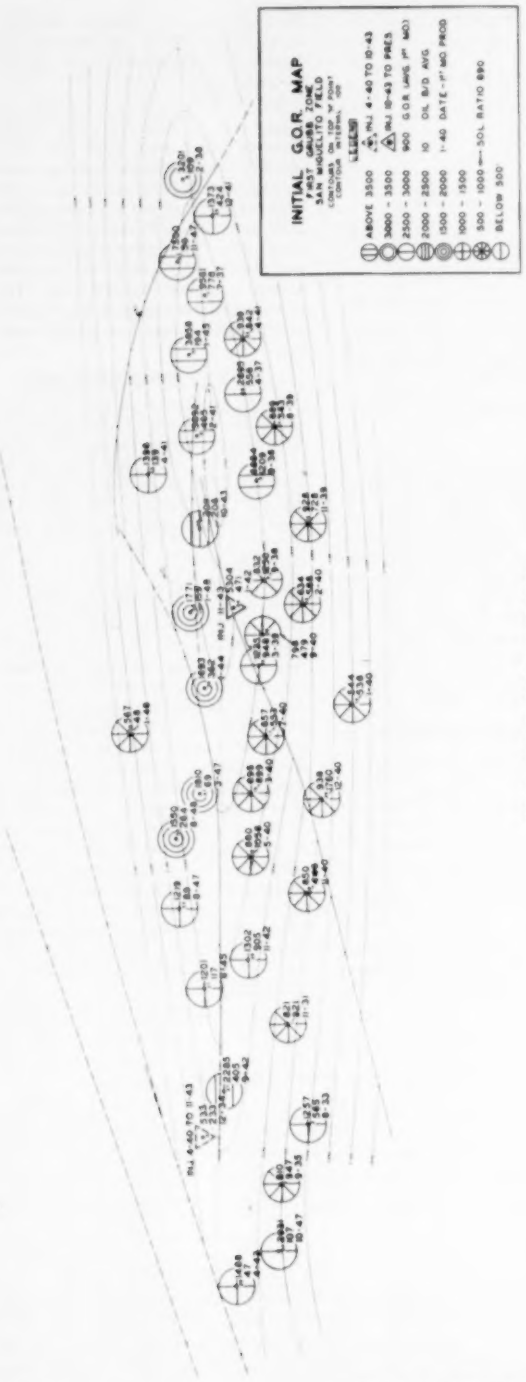


FIG. 9 — INITIAL GAS-OIL RATIO MAP.

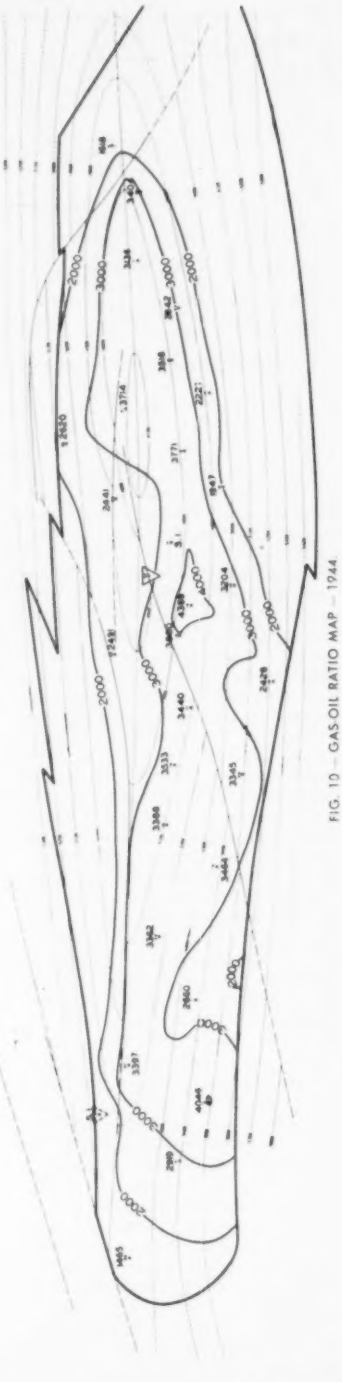


FIG. 10 — GAS-OIL RATIO MAP — 1944

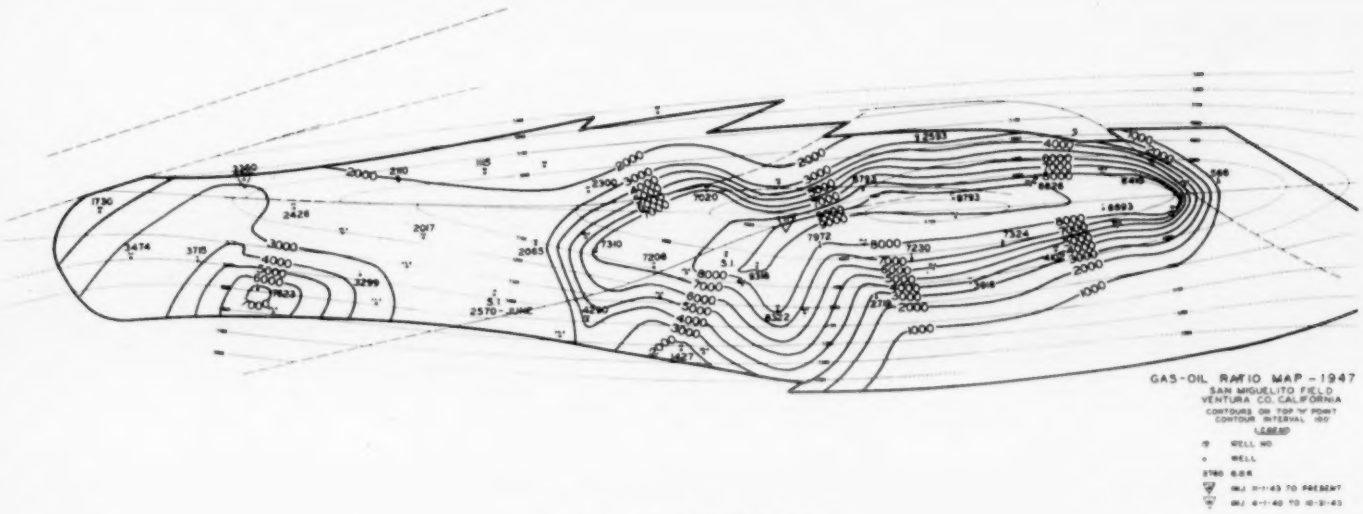


FIG. 10a — GAS OIL RATIO MAP — 1947

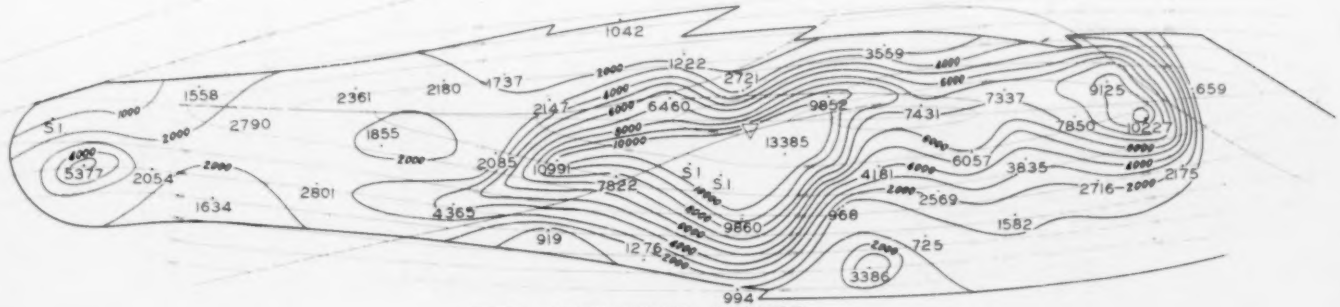


FIG. 10b — GAS-OIL RATIO MAP — MARCH, 1949.

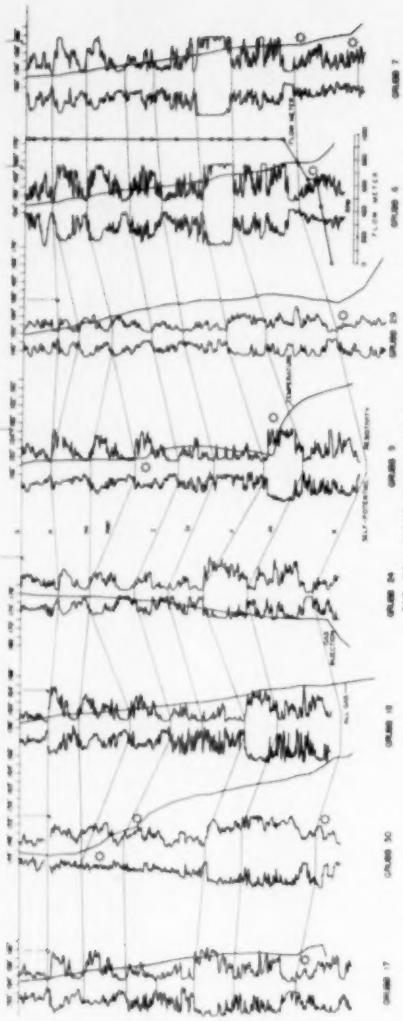


FIG. 11 — FLUID FLOW CHART.

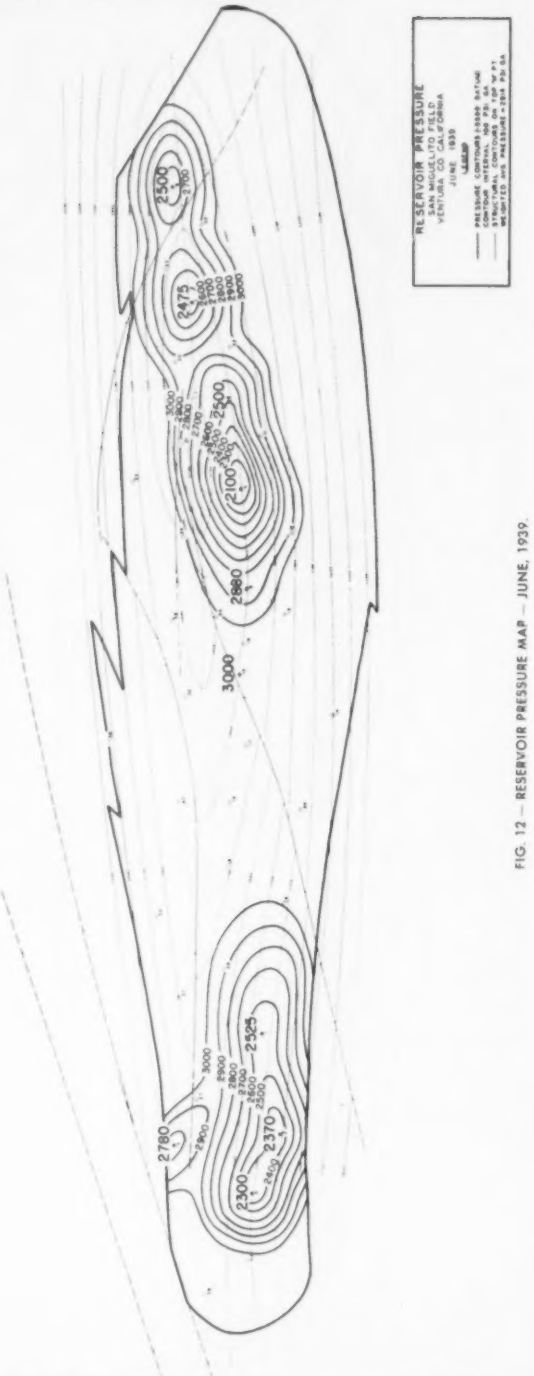


FIG. 12 — RESERVOIR PRESSURE MAP — JUNE, 1939.

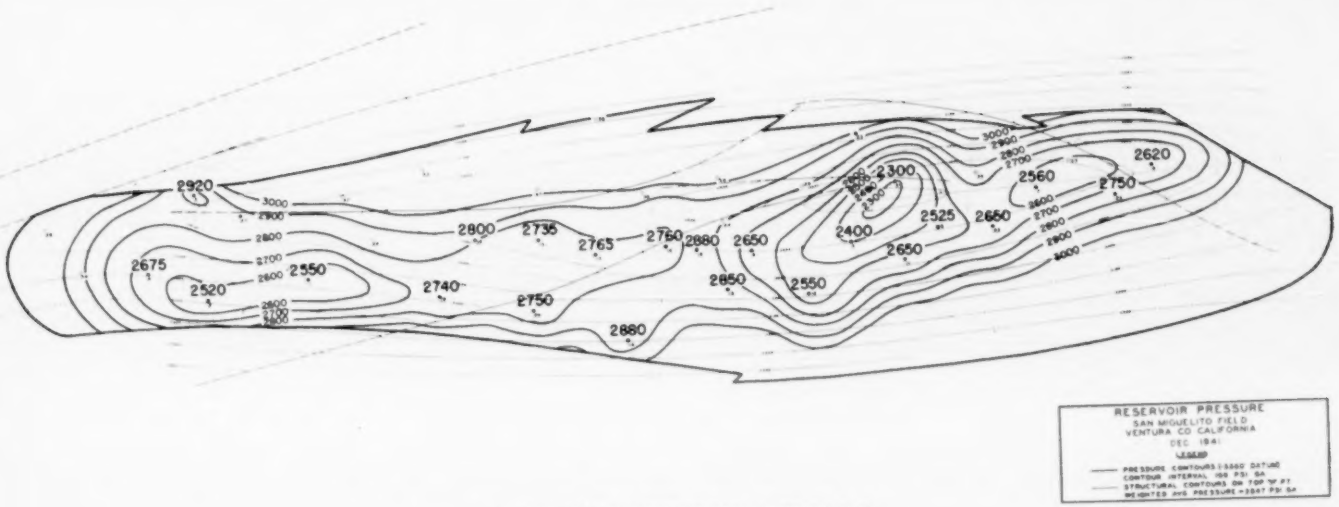


FIG. 12a — RESERVOIR PRESSURE MAP — DECEMBER, 1941.

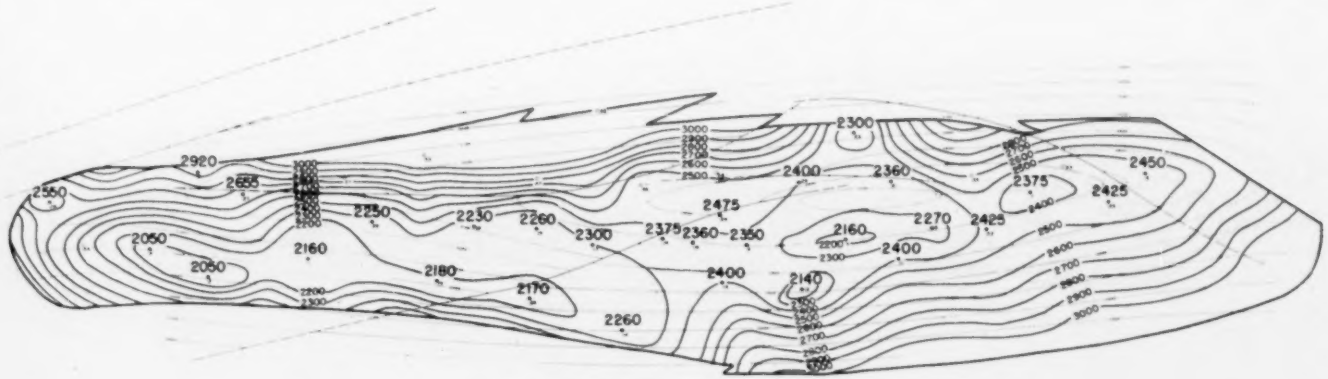


FIG. 12b — RESERVOIR PRESSURE MAP — DECEMBER, 1943.

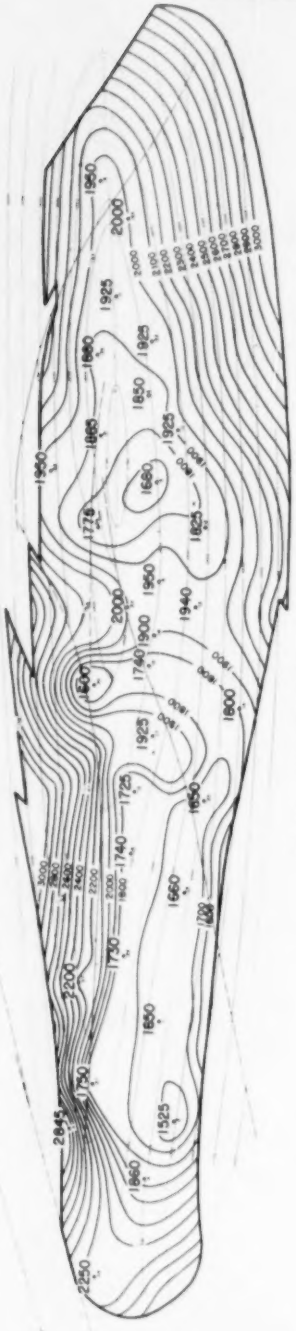


FIG. 12c — RESERVOIR PRESSURE MAP — SEPTEMBER, 1945.

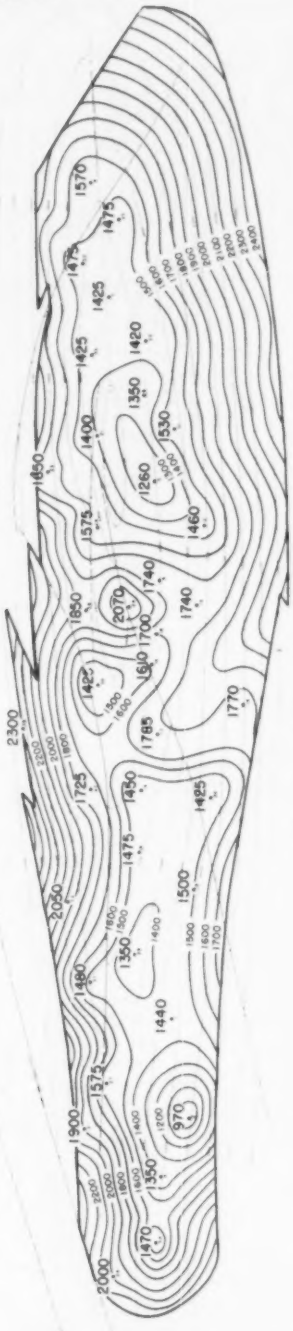


FIG. 12d — RESERVOIR PRESSURE MAP — MARCH, 1948.

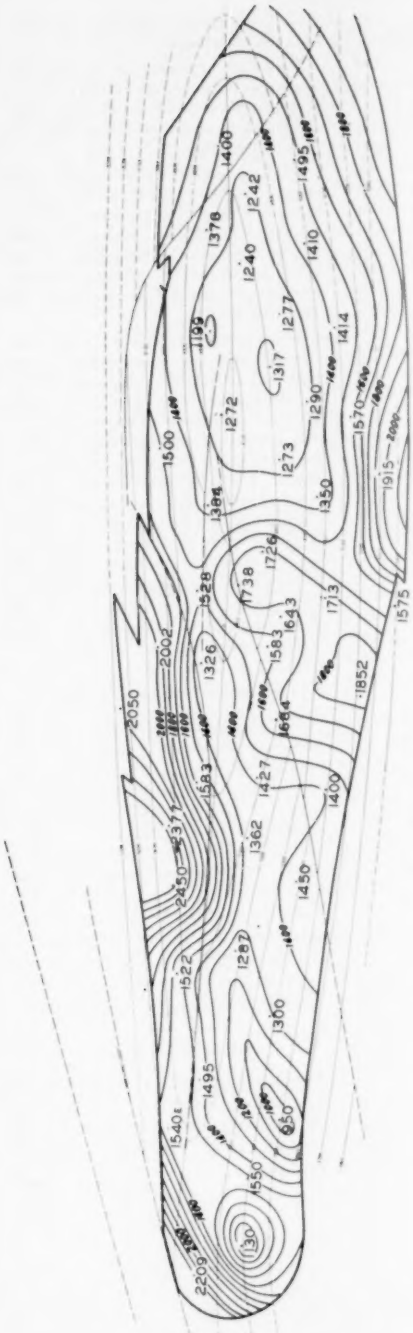


FIG. 12e — RESERVOIR PRESSURE MAP — MARCH, 1949.

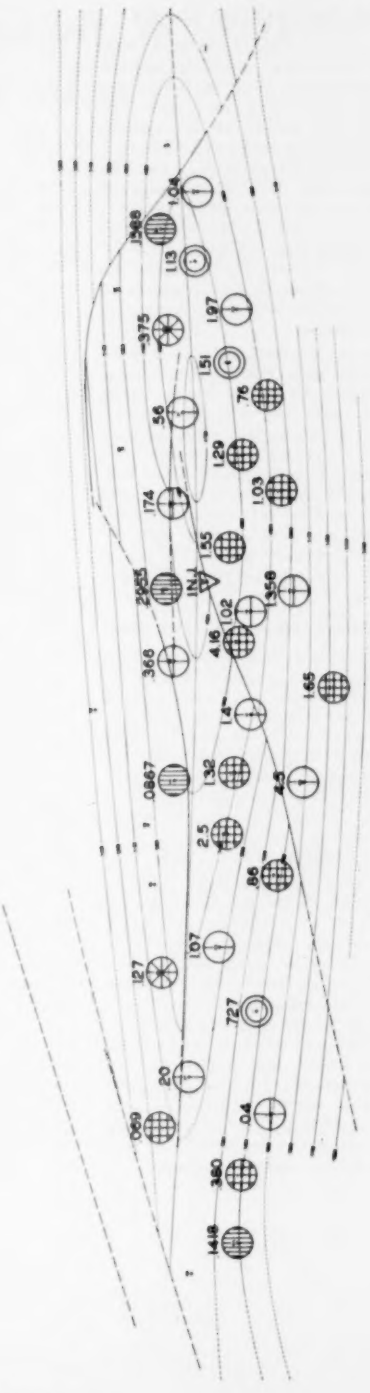


FIG. 13 — INITIAL PRODUCTIVITY INDEX MAP.

PRODUCTIVITY INDEX

A study of Fig. 13, Initial Productivity Index Map, reveals the uniform low permeability of the north flank and westerly area of the First Grubb Pool. Productivity indices of the recently completed south flank wells range from 1.7 to 2.1 B/D per lb per square in. pressure drop. The indicated potential of two of these wells was in excess of 1,000 B/D. This fact is significant in view of the stage of depletion of the reservoir, limited interval open and pressure decline to approximately 60 per cent of the estimated original well datum pressure.

The productivity index history of the high ratio wells, Fig. 6, reflects declining productivity indices with increasing gas-oil ratios. As the peak ratio is passed, the productivity index increases or its rate of decline is arrested. This characteristic may reflect relative saturation of oil and gas in a zone or zones not affected by gas channeling. As a rule, the rate of productivity index decline is directly proportional to permeability to oil and in turn structural position.

SPACING AND RECOVERIES

The spacing density of the First Grubb Pool was originally 10 acres per well. The density was based on such considerations as an average net sand thickness of 685 ft, relatively low permeability, topography, and other factors. As development proceeded, average density was increased to 6.5 acres per well. Present well density of the developed acreage ranges from 2.54 to approximately 8 acres per well.

Recoveries to date range from an average of 18 bbl per acre-ft on the north flank to an average of 136 bbl per acre-ft on the south flank. The recovery factors as shown by Table IV are grouped to illustrate stage of depletion, gravity drainage, and gas-oil segregation by gas-oil ratio brackets, structural elevation, and flank of the structure. The north flank low recovery reflects low permeability and productivity indexes of less than one-half of those on the south flank. The greater bbl per acre-ft recovery of the high gas-oil ratio group reflects stage of depletion and gas-oil segregation. This is further evidenced by the low recovery efficiency index of 52 bbl per lb drop for the area above 10,000 GOR as compared to 5,093 bbl from the low ratio group.

The recovery in terms of bbl per acre-ft and recovery index of bbl per lb drop of the low structure wells indicate effect of gravity segregation and drainage. This effect should become even more pronounced as the downstructure pressures are dissipated. Until recently, the low pressure area on the crest of the structure caused a pressure differential greater than gravity head, thus a tendency to flow oil up-dip. For this reason, gravity drainage in a part of the reservoir has been negligible.

As of August, 1948, the discovery well was pumping 27 B/D oil with a cut of 75 per cent after a cumulative recovery of 1,730,000 bbl. At that time it was whipstocked some 270 ft upstructure and recompleted in the "K to L" interval of the First Grubb zone, for an oil potential of 100 B/D. It is estimated that the ultimate recovery from this well will be nearly 2,000,000 bbl at the time of abandonment. Several wells have recovered nearly a million bbl. Pool cumulative recovery is 15,600,000 bbl.

CONCLUSIONS

The San Miguelito-First Grubb Pool has produced 15,500,000 bbl of oil, 45 billion cu ft of gas and one-third million bbl of water. Although there is evidence of a partial water drive in some sands within the First Grubb zone from the southern flank of the structure, the current rate of water encroachment is of such small magnitude that it does not affect the behavior of the solution-gas-drive reservoir. Material balance calculations have shown that water contiguous to this reservoir has been ineffective in maintaining pressure. The relatively small volume of gas injected in the crest of the structure has had no material effect on ultimate recovery. Gas injection has had an adverse effect on offset wells as a result of gas channeling. Past reservoir performance history under high pressure gas injection should not be construed as being indicative of the results to be obtained under future selectively controlled low-pressure gas injection.

Reservoir performance to date reflects gas channeling, effective gas-oil segregation, and effects of high withdrawal rates in a reservoir of relatively low permeability.

Faults, lamination of sands and shales, and heterogeneity of the producing sands affect the pressure and gas-oil ratio distribution within the First Grubb reservoirs; however, faults are not pressure barriers, with the possible exception of the one in the vicinity of Well No. 8.

The importance of determining true reservoir pressures in a steeply dipping high relief California type pool cannot be overemphasized. There is a 500-lb pressure differential between the top and bottom of the First Grubb zone. Volumetrically weighted mean well datum pressures have proved to be more accurate for reservoir mechanics calculations. Due to the time required for this method of pressure analysis, it is often desirable to determine a mean formation datum pressure, as is the custom, which is satisfactory for use in well comparisons and selective withdrawal control.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the management of the Continental Oil Co. for permission to publish the data used in this report. He desires to acknowledge the capable assistance of R. T. Hanson, J. H. Bolstad, John Van Riper, and Leroy Witt of the Pacific Coast Region. In addition, credit should be given M. H. Dubrow, Ponca City Production Department, John A. Murphy, and others of the Development and Research Department of Ponca City, Okla., for their valuable assistance and suggestions.

REFERENCE

M. B. Standing, "A Pressure-Volume-Temperature Correlation for Mixtures of California Oils and Gases." *API Drilling and Production Practice* (1947).

★ ★ ★

VOLUMETRIC BEHAVIOR OF OIL AND GAS FROM A LOUISIANA FIELD I

H. H. REAMER AND **B. H. SAGE,** CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIF., MEMBER AIME

ABSTRACT

An experimental investigation was conducted upon five different paired samples of oil and gas from a field in Louisiana. The study, with each pair of samples, included the measurement of the formation volume and the volume of the liquid phase for three mixtures of the oil and gas. The gas-oil ratio varied from approximately 200 to over 40,000 cu ft per bbl and measurements were made at temperatures between 40° and 250°F. The gravity of the tank oil for the five samples under investigation varied between 38.0° and 55.8° API.

The composition of the oil and gas samples and their mixtures is submitted in tabular form. A number of diagrams depicting the effect of temperature and gas-oil ratio upon retrograde dew-point pressure are presented.

INTRODUCTION

During the past two decades a fairly large number of investigations were made of the volumetric behavior of naturally occurring hydrocarbon mixtures. The earlier work of Beecher and Parkhurst[1] and a more recent report on samples from Dominguez Field[2] are typical of research of this nature. Such studies have been used in estimating the volumetric behavior of fluids in producing fields other than those from which samples were taken. Progress has been made[3,4,5] in correlating the influence of pressure, temperature, and composition upon the specific and formation volume of hydrocarbon mixtures of relatively low gas-oil ratios, but attempts to extend this correlation to higher ratios have not been particularly successful. The influence of composition upon the volumetric behavior of such systems cannot be simply related to a single parameter such as gas-oil ratio. In order to aid in the extension of the correlation of the volumetric behavior of mixtures of oil and gas to higher ratios, a rather complete study was made of five different pairs of samples from a Louisiana field. The complexity of the influence of composition upon the volumetric and phase behavior of such systems in the regions of retrograde condensation was indicated by earlier work,[6,7,8,9,10] and it is doubtful if simple correlations can be established in these regions with the information currently available. The terminology employed in this paper is identical to that utilized earlier.[10]

[1]References given at end of paper.

Manuscript received at the office of the Petroleum Branch February 21, 1950.

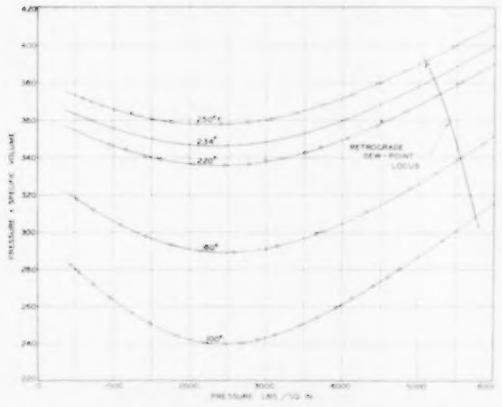


FIG. 1 — PRESSURE, SPECIFIC VOLUME PRODUCT FOR SYSTEM C CONTAINING 0.6912 WEIGHT FRACTION TRAP GAS.

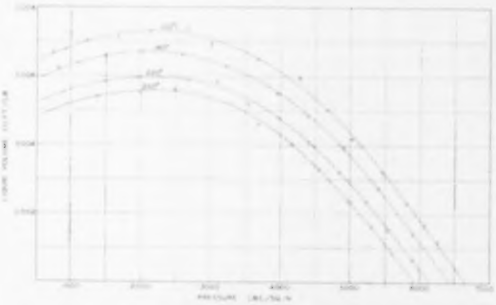


FIG. 2 — VOLUME OF LIQUID PHASE FOR SYSTEM C CONTAINING 0.6912 WEIGHT FRACTION TRAP GAS.

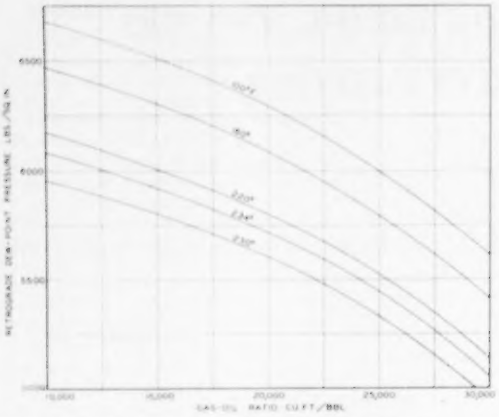


FIG. 3 — RETROGRADE DEW-POINT PRESSURES FOR SYSTEM C.

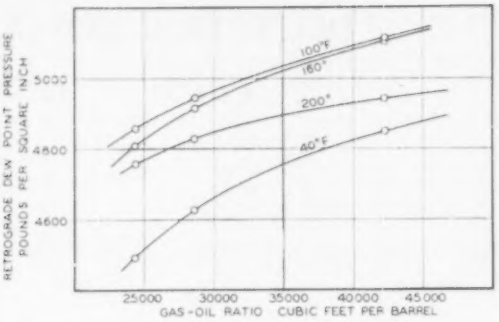


FIG. 6 — RETROGRADE DEW-POINT PRESSURE FOR SYSTEM A.

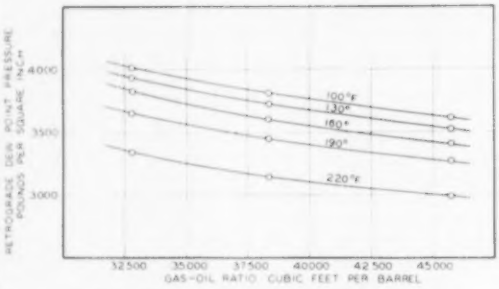


FIG. 4 — RETROGRADE DEW-POINT PRESSURES FOR SYSTEM E.

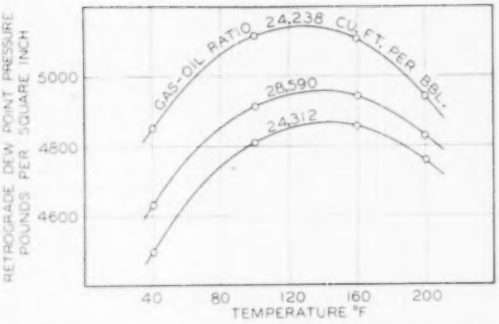


FIG. 7 — INFLUENCE OF TEMPERATURE UPON RETROGRADE DEW-POINT PRESSURE FOR SYSTEM A.

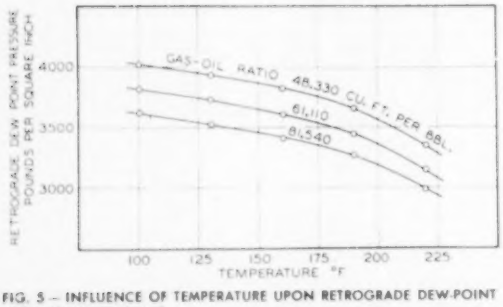


FIG. 5 — INFLUENCE OF TEMPERATURE UPON RETROGRADE DEW-POINT PRESSURE OF SYSTEM E.

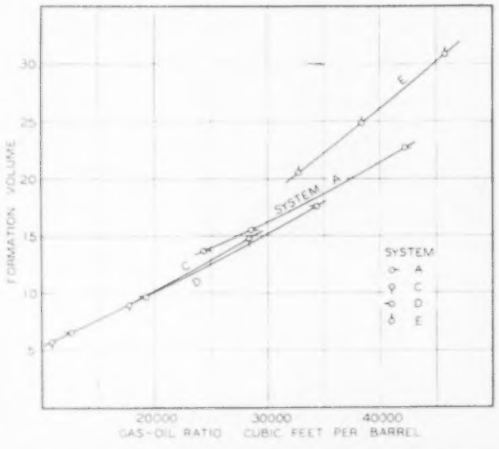


FIG. 8 — FORMATION VOLUME AT RETROGRADE DEWPOINT FOR 100°F.

Table I

Composition of Trap Samples

SYSTEM—A

Component	Gas		Liquid	
	Mole Fraction	Weight Fraction	Mole Fraction	Weight Fraction
Methane	0.94204	0.8582	0.1110	0.0163
Ethane	0.02820	0.0482	0.0214	0.0059
Propane	0.01303	0.0326	0.0353	0.0142
Isobutane	0.00433	0.0143	0.0252	0.0133
n-Butane	0.00303	0.0100	0.0299	0.0158
Isopentane	0.00154	0.0063	0.0875	0.0379
n-Pentane	0.00099	0.0037		
Hexanes	0.00129	0.0063	0.0875	0.0689
Heptanes	0.00070	0.0040	0.1274	0.1166
Carbon Dioxide	0.00400	0.0100	0.0042	0.0017
Octanes and heavier	0.00094[a]	0.0064	0.5006[f]	0.7094

SYSTEM—B

Methane	0.9150	0.8096	0.0334	0.0027
Ethane	0.0379	0.0628	0.0113	0.0017
Propane	0.0197	0.0479	0.0188	0.0041
Isobutane	0.0050	0.0160	0.0118	0.0034
n-Butane	0.0046	0.0147	0.0141	0.0041
Isopentane	0.0018	0.0072	0.0115	0.0042
n-Pentane	0.0010	0.0040	0.0135	0.0048
Hexanes	0.0013	0.0062	0.0385	0.0166
Heptanes	0.0005	0.0028	0.0765	0.0383
Octanes and heavier	0.0002[b]	0.0014	0.7706[g]	0.9201
Carbon Dioxide	0.0080	0.0194		
Air	0.0050	0.0080		

SYSTEM—C

Methane	0.9184	0.8134	0.1149	0.0159
Ethane	0.0378	0.0627	0.0347	0.0090
Propane	0.0148	0.0369	0.0349	0.0133
Isobutane	0.0038	0.0122	0.0191	0.0096
n-Butane	0.0027	0.0228	0.0247	0.0124
Isopentane	0.0028	0.0112	0.66	0.0166
n-Pentane	0.0010	0.0040	0.0202	0.0126
Hexanes	0.0010	0.0048	0.0802	0.05-7
Heptanes	0.0008	0.0044	0.1412	0.1222
Octanes and heavier	0.0005[c]	0.0035	0.5035[h]	0.7287
Carbon Dioxide	0.0070	0.0170		
Air	0.0050	0.0080		

SYSTEM—D

Methane	0.9281	0.8366	0.1190	0.0165
Ethane	0.0382	0.0645	0.0349	0.0091
Propane	0.0144	0.0357	0.0343	0.0131
Isobutane	0.0034	0.0111	0.0160	0.0081
n-Butane	0.0032	0.0104	0.0267	0.0134
Isopentane	0.0016	0.0065	0.0261	0.0163
n-Pentane	0.0007	0.0028	0.0214	0.0133
Hexanes	0.0015	0.0073	0.0827	0.0616
Heptanes	0.0007	0.0039	0.1317	0.1142
Octanes and heavier	0.0002[d]	0.0014	0.5072[i]	0.7344
Carbon Dioxide	0.0080	0.0198		

SYSTEM—E

Methane	0.9628	0.9011	0.1333	0.0217
Ethane	0.0168	0.0295	0.0178	0.0054
Propane	0.0089	0.0229	0.0242	0.0108
Isobutane	0.0025	0.0085	0.0131	0.0077
n-Butane	0.0030	0.0102	0.022	0.0134
Isopentane	0.0013	0.0055	0.0233	0.0169
n-Pentane	0.0008	0.0034	0.0221	0.0162
Hexanes	0.0014	0.0070	0.0876	0.0765
Heptanes	0.0011	0.0064	0.1579	0.1604
Octanes and heavier	0.0004[e]	0.0029	0.4672[j]	0.6708
Carbon Dioxide	0.0010	0.0026	0.0005	0.0002

Average molecular weight of less volatile constituents:
a. 120.0 c. 125 e. 125
b. 125 d. 125
Average molecular weight as determined from freezing point lowering of benzene:
f. 185.2 h. 167.6 j. 133
g. 238.9 i. 167.4

MATERIALS

The samples of oil and gas from each of several surface primary separators were obtained and forwarded to this laboratory in appropriate pressure vessels. Subsamples were withdrawn from each of the pressure vessels containing liquid phase samples by appropriate displacement procedures involving the use of ethylene glycol. These subsamples were dried by passage through chambers packed with granular calcium chloride. The samples of the trap gas were withdrawn from the primary gas containers after the vessels had been maintained at a temperature in excess of 250°F for several hours. This procedure was followed in order to avoid the possibility of the partial condensation of portions of the trap gas in the original container. The subsamples were forwarded to an industrial laboratory where the composition of the trap liquid and trap gas was determined by appropriate fractionation analysis.

The results of these analytical measurements are reported in terms of both mole and weight fractions. The latter variable is included because of uncertainties as to the molecular weight of the octanes and heavier fractions of the trap liquid and trap gas samples. In the case of the trap liquid samples, the molecular weight of the octanes and heavier hydrocarbons was obtained from the freezing point of benzene.

PROCEDURES

The equipment used in this study[9] and the techniques employed in the determination of the quantity of each of the phases have already been presented in the literature.[10,12,13] For this reason, it is not necessary to review in detail the laboratory approach to this investigation. In principle, it consisted of introducing appropriate quantities of the trap liquid into a closed vessel in which the sample was confined over mercury. The quantity of this hydrocarbon sample was established from volumetric measurements carried out upon a trap liquid sample of known weight. The weight of trap gas was established by direct gravimetric techniques making use of weighing bombs.[14] The total volume of the mixture of trap liquid and trap gas was determined as a function of pressure for a series of temperatures. In addition, the total volume of the liquid phase was established throughout the greater part of the heterogeneous region. This information was obtained by the direct measurement of the relative elevation of the mercury-hydrocarbon and the hydrocarbon liq-

uid-gas interfaces. The details of this method have been described.[11] These measurements were carried out at temperatures between 40° and 320°F. In all cases at least three different temperatures were investigated and in some cases as many as five were studied.

Experimental data were obtained for a series of different gas-oil ratios for each set of samples of trap liquid and trap gas. An effort was made to use as nearly identical methods as possible in the studies of each set of samples. Some minor changes in procedure were required but it is not believed that these variations significantly influenced the results.

DESCRIPTION OF SAMPLES

Five sets of corresponding samples of trap liquid and trap gas were obtained from the field and are identified in this text by the letters *A* to *E* inclusive. The composition of the trap liquid and trap gas for each set is presented in Table I. The weight and mole fractions of the lighter hydrocarbons were tabulated with similar information for each of the fractions making up the octanes and heavier portion of the trap liquid samples. In the footnotes to Table I, attention is called to additions or variations in the tabular information for the several sets of trap samples.

The physical properties of the octanes and heavier portion of the five trap liquid samples are presented in Table II. These data are supplemented by more limited information concerning the characteristics of several portions of the overhead obtained from the fractionation of the octanes-and-heavier portions at reduced pressures. As an added characterization, the viscosity-gravity factor[12] was computed for each of the fractions as well as for the octanes-and-heavier parts of the trap liquid samples as a whole. It is believed that the information contained in Tables I and II permits a fairly complete evaluation of the quantities of the lighter hydrocarbons in each of the mixtures of trap sample investigated and gives at least a rough indication of the principal characteristics of the octanes-and-heavier hydrocarbons making up these samples. Since the data submitted for each of the corresponding sets of samples are similar, a direct comparison of the characteristics may be obtained.

The relative quantities of the lighter hydrocarbons in the liquid phase recovered from the stock tank for each of the trap samples are recorded in Table III. The compositions of the corresponding trap samples and tank oil have been

Table II

Properties of Octanes and Heavier — Portion of Trap Liquid Sample

	System-A	System-B	System-C	System-D	System-E
Specific Gravity °API 60°F, atmospheric pressure	47.5	35.4	43.8	43.2	49.8
Specific Volume 60°F, atmospheric pressure	0.020276	0.018917	0.01987	0.01980	0.020543
Average molecular weight	155.2	238.9	167.6	167.4	153
Kinematic viscosity: centistokes					
77°F	1.5841				
100°F	1.2779				
Viscosity gravity factor	0.8080				

SYSTEM—A

Cut No.	Specific Gravity 60°F/60°F	Kinematic Viscosity Centistokes 77°F	100°F	Viscosity Gravity Factor	Boiling Range °F	Weight* Fraction
1	0.7489	0.7395	0.6430	0.792	244–266	0.06740
2	0.7545	0.7912	0.6839	0.795	266–284	0.06790
3	0.7641	0.8800	0.7617	0.801	284–318	0.06876
4	0.7674	1.0487	0.8880	0.798	318–347	0.06906
5	0.7756	1.2627	1.0514	0.800	347–377	0.06980
6	0.7881	1.5762	1.3018	0.806	377–415	0.07092
Residue	0.8211	3.8393	2.8759	0.816	—	0.29558

SYSTEM—B

1	0.7682	0.806	0.706	0.805	240–340	0.0833
2	0.7880	1.283	1.135	0.811	340–419	0.0855
3	0.8099	2.511	1.942	0.815	419–484	0.0879
Residue	0.8735	35.05	21.53	0.829	484	0.6634

SYSTEM—C

1	0.7684	0.729	0.636	0.8164	248–268	0.0694
2	0.7717	0.806	0.693	0.8160	268–302	0.0697
3	0.7798	0.977	0.831	0.8160	302–347	0.0704
4	0.7884	1.209	1.075	0.8148	347–392	0.0712
5	0.7952	1.477	1.433	0.8146	392–436	0.0722
6	0.8100	2.465	1.928	0.8166	436–472	0.0732
Residue	0.8377	7.454	5.119	0.8181	472	0.3026

SYSTEM—D

1	0.7750	0.725	0.643	0.8240	236–274	0.0702
2	0.7755	0.783	0.685	0.8210	274–298	0.0703
3	0.7811	0.913	0.787	0.8202	298–336	0.0708
4	0.7894	1.218	1.027	0.8173	336–379	0.0715
5	0.7988	1.663	1.361	0.8161	379–428	0.0724
6	0.8143	2.392	1.872	0.8216	428–473	0.0738
Residue	0.8427	7.339	5.106	0.8240	473	0.3053

SYSTEM—E

1	0.7494	0.779	0.683	0.7892	252–276	0.0641
2	0.7536	0.807	0.700	0.7940	276–285	0.0645
3	0.7606	0.871	0.759	0.7973	285–304	0.0651
4	0.7685	0.962	0.822	0.8032	304–321	0.0658
5	0.7758	1.097	0.923	0.8060	321–348	0.0664
6	0.7897	1.296	1.084	0.8100	348–376	0.0671
7	0.7930	1.410	1.315	0.8120	376–412	0.0678
8	0.8029	2.134	1.695	0.8120	412–446	0.0687
Residue	0.8264	4.268	3.143	0.8190	446 +	0.1413

* Based upon the entire trap liquid sample.

Table III

Composition of Tank Oil

SYSTEM—A

Component	Mole Fraction	Weight Fraction
Methane	...	...
Ethane	...	...
Propane	0.01461	0.00580
Isobutane	0.01986	0.00895
n-Butane	0.02585	0.01165
Pentanes	0.06235	0.03488
Hexanes	0.09830	0.06568
Heptanes	0.14919	0.11591
Octanes and heavier	0.62984	0.75793

SYSTEM—B[a]

Methane	...	...
Ethane	...	...
Propane	0.0161	0.0034
Isobutane	0.0099	0.0027
n-Butane	0.0125	0.0034
Isopentane	0.0112	0.0038
n-Pentane	0.0133	0.0046
Hexanes	0.0347	0.0142
Heptanes	0.0812	0.0386
Octanes and heavier	0.8211	0.9293

SYSTEM—C[b]

Methane	...	...
Ethane	...	...
Propane	0.0144	0.0046
Isobutane	0.0123	0.0051
n-Butane	0.0248	0.0103
Isopentane	0.0422	0.0218
n-Pentane	0.0127	0.0065
Hexanes	0.0826	0.0510
Heptanes	0.1499	0.1075
Octanes and heavier	0.6611	0.7932

SYSTEM—D[c]

Methane	...	...
Ethane	...	...
Propane	0.0208	0.0067
Isobutane	0.0168	0.0071
n-Butane	0.0254	0.0108
Isopentane	0.0338	0.0178
n-Pentane	0.0259	0.0136
Hexanes	0.0823	0.0517
Heptanes	0.1506	0.1167
Octanes and heavier	0.6354	0.7756

SYSTEM—E[d]

Methane	0.0092	0.0013
Ethane	0.0049	0.0013
Propane	0.0158	0.0061
Isobutane	0.0118	0.0060
n-Butane	0.0228	0.0117
Isopentane	0.0258	0.0164
n-Pentane	0.0250	0.0159
Hexanes	0.1026	0.0780
Heptanes	0.1877	0.1659
Octanes and heavier	0.5944	0.8974

Gravities of the tank oil at 60°F
a. 38.9° API
b. 49.5° API
c. 49.4° API
d. 55.8° API

used to determine the relationship of the gas-oil ratio to the composition of the mixture. The methods whereby this was accomplished have already been described.[10,13,14]

EXPERIMENTAL RESULTS

The compressibility factors of trap gas sample *A* are shown in Table IV. The behavior of this multicomponent hydrocarbon mixture is similar to that reported in earlier investigations.[12] The information submitted forms additional confirmation of the possibility of predicting within reasonable limits the volumetric behavior of natural gas.[10,11]

The composition of the experimentally studied mixtures for each of the several sets of samples is recorded in Table V. The corresponding values of the gas-oil ratio as well as the weight and mole fraction of the principal components are included in this tabulation. The methods employed in arriving at the several derived quantities presented in Table V have already been described.[12] The results of the experimental investigation of the five sets of mixtures are available.[10] A sample of these data for System *A* at 40°F is shown in Table VI. In each table, the specific volume, the volume of the liquid phase per unit weight of mixture, and the formation volume are recorded for a series of even valued pressures for each of the temperatures studied.

The qualitative significance of the results is already available in the literature [10,12,13] and for this reason only a limited number of figures pertaining to the volumetric behavior are included in this text. In Fig. 1 for System *C* is presented the product of the pressure and the specific volume for a mixture containing 0.6912 weight fraction trap gas. As a matter of interest the locus of the retrograde dew-point state has been indicated. No significant discontinuity in the relationship of the first derivative of the product of the pressure and volume with respect to pressure is discernible at dew point. Fig. 2 portrays the variation in the volume of the liquid phase per unit weight of mixture as a function of pressure for the same system. The nearly linear decrease in the volume of the liquid phase with increase in pressure for states at pressures above 4,500 psi is characteristic of materials of this type.

In Fig. 3 the variation of the retrograde dew-point pressure with gas-oil ratio is shown for System *C*. Similar information is presented in Fig. 4 for System *E*. In both of these cases an iso-

thermal increase in gas-oil ratio causes a decrease in the retrograde dew-point pressure. The influence of temperature upon the retrograde dew-point pressure for System *E* for several different gas-oil ratios is indicated in Fig. 5. An increase in temperature results in a decrease in the retrograde dew-point pressure for both Systems *C* and *E*. A somewhat different behavior is presented in Fig. 6 for System *A*. In this instance an increase in gas-oil ratio is associated with an increase in the retrograde dew-point pressure but this effect is less pronounced at the higher temperatures. Fig. 7 shows that the retrograde dew-point pressure for System *A* reaches a maximum at temperatures between 120° and 150°F for gas-oil ratios between 42,000 and 24,000. This indicates a somewhat more complex behavior than was encountered for the other mixtures.

The formation volume at retrograde dew-point is depicted as a function of gas-oil ratio in Fig. 8 for 100°F. In this instance there is a similarity in the behavior of the several systems investigated. In each case an increase in gas-oil ratio resulted in an increase in formation volumes at retrograde dew-point. Similar behavior was found at the higher temperatures.

No simple relationship of retrograde dew-point pressure to the properties of tank oil appears to exist for this system as was the case for another investigation[7] of a similar nature. With the exception of System *B* all of the formation volumes in the heterogeneous region can be related to the prevailing gas-oil ratio, temperature, and pressure by the following expression:

$$v = \frac{ArT}{p} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The values of the coefficient *A* are presented as a function of temperature and pressure in Table VII. It is apparent that there is but little variation in this constant with change in pressure and temperature. Equation 1 should not be employed at gas-oil ratios below 5 Mcf per bbl since large discrepancies are encountered at the lower gas-oil ratios. The data for System *D* which were limited to gas-oil ratios below 1,500 cu ft per bbl were not employed in the establishment of the coefficients of Table VII. These coefficients apply only to systems of the same general type as have been studied here. However, their magnitude is similar to such coefficients found earlier.[7] The ability to obtain a simple correlation over a wide range of gas-oil ratios, temperatures, and pres-

Table IV

Compressibility Factors for Trap Gas Sample

Pressure PSI Absolute	40°F	100°F	160°F	200°F
0	1.0000	1.0000	1.0000	1.0000
200	0.9563	0.9693	0.9808	0.9853
400	0.9134	0.9417	0.9628	0.9716
600	0.8731	0.9165	0.9458	0.9590
800	0.8344	0.8935	0.9305	0.9480
1000	0.7970	0.8725	0.9236	0.9383
1250	0.7540	0.8495	0.9035	0.9282
1500	0.7210	0.8303	0.8924	0.9203
1750	0.6985	0.8158	0.8844	0.9143
2000	0.6864	0.8060	0.8788	0.9103
2250	0.6835	0.8009	0.8758	0.9085
2500	0.6882	0.8002	0.8750	0.9089
2750	0.6990	0.8039	0.8770	0.9112
3000	0.7145	0.8115	0.8815	0.9155
3250	0.7353	0.8228	0.8888	0.9218
3500	0.7548	0.8369	0.8980	0.9297
3750	0.7784	0.8531	0.9096	0.9390
4000	0.8032	0.8710	0.9227	0.9500
4250	0.8294	0.8905	0.9373	0.9620
4500	0.8565	0.9114	0.9533	0.9752
4750	0.8838	0.9334	0.9703	0.9395
5000	0.9118	0.9559	0.9880	1.025

Table VI

Sample

Volumetric Behavior of Experimentally Studied Mixtures

SYSTEM—A

Weight Fraction Trap Gas = 0.7972
Gas-Oil Ratio = 24,312

Pressure PSI Absolute	Specific Volume Cu Ft/Lb	Liquid Volume Cu Ft/Lb	Formation Volume
	40°F		
	1494/a		
R.D.P.	0.04903	0	12.34
0	∞		∞
200	1.1908		299.7
400	0.7509		189.0
600	0.3563	0.00502	89.67
800	0.2552	0.00542	64.23
1000	0.1964	0.00571	49.42
1250	0.1506	0.00593	37.98
1500	0.1219	0.00597	30.67
1750	0.1020	0.00586	25.67
2000	0.08803	0.00562	22.15

Table VII

Values of Coefficient

$Ax10^3$

Pressure PSIA	40° F[a]	100°	160°	220°	250°[b]
600	4.45	4.75	4.90	5.03	5.08
1000	4.07	4.51	4.74	4.93	5.00
1500	3.75	4.29	4.59	4.84	4.93
2000	3.59	4.16	4.51	4.80	4.89
3000	3.70	4.21	4.52	4.81	4.93
4000	4.19	4.55	4.75	5.01	5.09
5000		4.99	5.11	5.30	5.36

a Based on data for System A only.
b Farrell-Young data for Systems C and D.

Table V

Compositions of Experimentally Studied Mixtures

SYSTEM—A

Component	Weight Fraction Trap Gas: 0.7972 Mole Fraction	0.7972 Weight Fraction	0.8222 Mole Fraction	0.8222 Weight Fraction	0.8727 Mole Fraction	0.8727 Weight Fraction
Methane	0.90940	0.68748	0.91410	0.70856	0.92323	0.75102
Ethane	0.02793	0.03958	0.02797	0.04065	0.02804	0.04277
Propane	0.01390	0.02889	0.01378	0.02935	0.01355	0.03028
Isobutane	0.00515	0.01410	0.00503	0.01412	0.00481	0.01417
n-Butane	0.00408	0.01119	0.00393	0.01104	0.00365	0.01075
Isopentane	0.00374	0.01272	0.00342	0.01194	0.00282	0.01033
n-Pentane	0.00086	0.00294	0.00087	0.00303	0.00061	0.00322
Hexanes	0.00468	0.01900	0.00418	0.01744	0.00327	0.01428
Heptanes	0.00568	0.02881	0.00496	0.02401	0.00361	0.01832
Octanes and heavier	0.02057	0.14898	0.01774	0.13136	0.01241	0.09502
Carbon Dioxide	0.00401	0.00831	0.00402	0.00852	0.00400	0.00894
Gas-Oil Ratio =	24,312		28,590		42,238	

SYSTEM—B

Component	Weight Fraction Trap Gas: 0.05611 Mole Fraction	0.05611 Weight Fraction	0.09859 Mole Fraction	0.09859 Weight Fraction	0.13645 Mole Fraction	0.13645 Weight Fraction
Methane	0.3827	0.0480	0.5156	0.0822	0.5937	0.1128
Ethane	0.0218	0.0051	0.0259	0.0077	0.0282	0.0100
Propane	0.0191	0.0066	0.0193	0.0084	0.0194	0.0101
Isobutane	0.0091	0.0041	0.0081	0.0047	0.0075	0.0051
n-Butane	0.0103	0.0047	0.0089	0.0052	0.0081	0.0056
Isopentane	0.0077	0.0043	0.0062	0.0044	0.0053	0.0046
n-Pentane	0.0085	0.0048	0.0066	0.0048	0.0055	0.0047
Hexanes	0.0238	0.0160	0.0182	0.0156	0.0149	0.0152
Heptanes	0.0464	0.0363	0.0349	0.0348	0.0282	0.0334
Octanes and heavier	0.4654	0.8686	0.3492	0.8295	0.2809	0.7948
Carbon Dioxide	0.0032	0.0011	0.0044	0.0019	0.0051	0.0026
Air	0.0020	0.0004	0.0027	0.0008	0.0032	0.0011
Gas-Oil Ratio =	398.7		705.5		1003.9	

SYSTEM—C

Component	Weight Fraction Trap Gas: 0.6912 Mole Fraction	0.6912 Weight Fraction	0.8051 Mole Fraction	0.8051 Weight Fraction	0.8928 Mole Fraction	0.8928 Weight Fraction
Methane	0.8659	0.5672	0.8891	0.6580	0.9035	0.7280
Ethane	0.0376	0.0462	0.0377	0.0523	0.0377	0.0570
Propane	0.0161	0.0290	0.0155	0.0316	0.0152	0.0336
Isobutane	0.0048	0.0114	0.0044	0.0117	0.0041	0.0119
n-Butane	0.0082	0.0196	0.0077	0.0208	0.0074	0.0217
Isopentane	0.0044	0.0128	0.0037	0.0122	0.0032	0.0117
n-Pentane	0.0022	0.0066	0.0017	0.0057	0.0014	0.0049
Hexanes	0.0062	0.0217	0.0039	0.0154	0.0025	0.0106
Heptanes	0.0100	0.0408	0.0059	0.0274	0.0034	0.0171
Octanes and heavier	0.0334	0.2274	0.0189	0.1448	0.0098	0.0812
Carbon Dioxide	0.0065	0.0118	0.0067	0.0137	0.0069	0.0152
Air	0.0047	0.0055	0.0048	0.0064	0.0049	0.0071
Gas-Oil Ratio =	13,398		24,589		49,412	

SYSTEM—D

Component	Weight Fraction Trap Gas: 0.7073 Mole Fraction	0.7073 Weight Fraction	0.7996 Mole Fraction	0.7996 Weight Fraction	0.8972 Mole Fraction	0.8972 Weight Fraction
Methane	0.8796	0.5964	0.8980	0.6722	0.9141	0.7521
Ethane	0.0380	0.0483	0.0381	0.0534	0.0381	0.0588
Propane	0.0156	0.0291	0.0151	0.0312	0.0147	0.0334
Isobutane	0.0042	0.0102	0.0039	0.0105	0.0036	0.0108
n-Butane	0.0046	0.0113	0.0041	0.0111	0.0036	0.0108
Isopentane	0.0031	0.0094	0.0025	0.0085	0.0020	0.0075
n-Pentane	0.0019	0.0059	0.0015	0.0049	0.0011	0.0039
Hexanes	0.0064	0.0232	0.0045	0.0182	0.0029	0.0129
Heptanes	0.0085	0.0362	0.0056	0.0260	0.0030	0.0153
Octanes and heavier	0.0306	0.2160	0.0190	0.1482	0.0090	0.0768
Carbon Dioxide	0.0075	0.0140	0.0077	0.0158	0.0079	0.0177
Gas-Oil Ratio =	14,780		24,300		52,938	

SYSTEM—E

Component	Weight Fraction Trap Gas: 0.9308 Mole Fraction	0.9308 Weight Fraction	0.9097 Mole Fraction	0.9097 Weight Fraction	0.8884 Mole Fraction	0.8884 Weight Fraction
Methane	0.9522	0.8403	0.9487	0.8218	0.9451	0.8030
Ethane	0.0168	0.0278	0.0168	0.0273	0.0168	0.0268
Propane	0.0091	0.0221	0.0092	0.0218	0.0092	0.0216
Isobutane	0.0026	0.0084	0.0027	0.0084	0.0027	0.0084
n-Butane	0.0033	0.0104	0.0033	0.0105	0.0034	0.0105
Isopentane	0.0016	0.0063	0.0017	0.0065	0.0018	0.0067
n-Pentane	0.0011	0.0043	0.0012	0.0045	0.0013	0.0048
Hexanes	0.0025	0.0118	0.0029	0.0133	0.0032	0.0148
Heptanes	0.0031	0.0171	0.0037	0.0203	0.0045	0.0236
Octanes and heavier	0.0067	0.0491	0.0088	0.0632	0.0110	0.0775
Carbon Dioxide	0.0010	0.0024	0.0010	0.0024	0.0010	0.0023
Gas-Oil Ratio =	81,540		61,110		48,330	

sures for the four systems investigated indicates a similarity in behavior. The average deviation of the values of the coefficient A for the several systems at a given pressure and temperature was 0.057. The maximum deviation encountered was 0.13 at 5,000 psi at 100°F for System A.

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CRITICAL ANALYSIS OF THE EFFECT OF WELL DENSITY ON RECOVERY EFFICIENCY

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ABSTRACT

The various theories as to the well spacing-recovery relationship are reviewed in considerable detail and these theories analyzed in terms of their consistency with modern reservoir engineering concepts. It is concluded that the well spacing problem must be analyzed in terms of recovery efficiency and that a positive answer to the relation between well density and recovery efficiency is not available from direct comparisons of the production histories of wells and fields.

The results of an engineering analysis designed to permit approximate calculation of recovery efficiencies as a function of well spacing in a depletion type reservoir from basic reservoir data is presented. Results of this type analysis indicate that the effect of well spacing on recovery efficiency in depletion type reservoirs can be expected to be very small. Limitations of this approach are pointed out, particularly with respect to its application in lenticular reservoirs.

Testing techniques are outlined which should indicate whether or not a reservoir is continuous between wells and whether or not satisfactory drainage is being obtained with present spacings. A mass of data of this type indicates continuity to exist in most fields.

INTRODUCTION

The purpose of this paper is to review critically the engineering aspects of the well spacing problem, both from the standpoint of certain concepts and from the standpoint of reservoir mechanics. The well spacing problem is primarily an economic problem in which the optimum well density for a particular field is that density which will yield the greatest oil recovery consistent with justifiable development costs. The well spacing answer in terms of economic conditions, however, is extremely sensitive to the variation in recovery efficiency with well density. The variation in recovery efficiency with well density is properly an engineering problem. Different opinions as to the correct answer to this engineering problem is the basis for most of the wide difference in opinion among various members of the industry as to optimum well spacing. This paper will be confined to the engineering problem of the relation between well density and ultimate oil recovery; economic considerations necessary for the evaluation of optimum well density for any particular field will not be discussed.

The paper can be logically divided into two parts. The first part deals with a critical examination of the background and logic of the Cutler Rule and of similar studies by other authors and of related well spacing concepts. It is indicated that the variations in recoveries with well density* observed by Cutler and others can be logically attributed to regional migration. Theoretical justification of the Cutler type relation wherein observed variations in recovery with well density in the same field is attributed to variations in recovery effiiency, in terms of energy relations, is refuted.

The second part consists of a review of concepts of reservoir mechanics with regard to the well density-recovery relation. It is indicated that little variation of recovery efficiency with well density can be expected in a depletion type reservoir, unless lenticular conditions prevent communication between wells. The significance of field test data with regard to the existence or non-existence of lenticular conditions is pointed out.

THE CUTLER RULE†

The first published article concerning the engineering aspects of the well spacing problem to receive wide attention was the work of W. W. Cutler[1] of the U. S. Bureau of Mines, published in 1924. In a study of decline curves from a large

[1]References given at end of paper.

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*The expression "well density" as utilized herein refers to the number of acres attributed to each well in a uniform well pattern, and is expressed in acres per well. The term "well spacing" is utilized to denote the average distance between adjacent wells in a uniform well pattern.

†Although the Cutler rule is treated critically in this discussion, the authors intend no personal criticism of W. W. Cutler or of his work. The currently accepted concepts of reservoir mechanics were nonexistent at the time of Cutler's work, as were even the most basic tools (such as the bottom hole pressure bomb) for observing reservoir behavior.

number of fields, Cutler observed a variation in physical recoveries of wells on tracts developed to different densities in the same field. He analyzed, with regard to the well spacing relation, the recoveries of tracts drilled to different well densities in the same field, including data from seven separate fields. These data consisted only of examples which apparently satisfied the following requirements:

1. The wells being compared had approximately the same initial productive capacity as exhibited by the first year's production and were completed at approximately the same time, in areas of approximately equal pay thickness.
2. The wells being compared exhibited interference with offset wells as indicated by changes in the slope of decline curves of old wells upon completion of nearby new wells.

From these comparative data was developed the following tentative rule: *The ultimate production for wells of equal size where there is interference . . . seem approximately to vary directly as the square roots of the areas drained by the wells.* The *areas drained by the wells* is considered to be the area of the tract in question divided by the number of wells on that tract; in short, the areas attributed to those wells. The rule can be restated to the effect that the average recovery per acre should be inversely proportional to the square roots of the area drained by (attributed to) each well. All the examples represented by Cutler's data apparently were depletion type gas drive reservoirs which were produced at unrestricted rates.

It is apparent that the variation in recoveries with well density observed by Cutler must be attributed to either or both of two factors:

1. Regional migration into the areas of closer spacing.
2. Higher recovery efficiency from beneath the areas of closer spacing.

If the variations in recovery can be attributed to variations in recovery efficiency, then it follows that Cutler's Rule can be applied on a field-wide basis with regard to total recovery from the field. If the variation in recovery is due to regional migration, the rule cannot be applied on a field-wide basis with regard to field-wide recoveries. Although the rule itself makes no provision with regard to the cause of the observed variation of recovery with well density, it is apparent from Cutler's justification of his rule, in terms of energy relations, that he attributed the variation in recovery entirely to a variation in recovery efficiency. It is in the light of this interpretation that the Cutler Rule has been advanced by advocates of close spacing as a guide to increasing oil recoveries. An examination of Cutler's justification of the rule on the basis of energy relations, wherein the variation in recovery with well spacing is attributed to variation in recovery efficiency with well spacing, indicates the justification to be invalid on two separate grounds:

1. Linear flow principles were utilized, whereas radial flow conditions actually apply.
2. Energy relations themselves are incorrectly applied.

A quantitative evaluation of the severity of regional migration between tracts drilled to different densities in the same field indicates that the behavior reflected by Cutler's Rule might easily be attributed entirely to regional migration.

Cutler's justification, on the basis of energy relations, of his opinion that the observed differences in recovery should be attributed to a variation in recovery efficiency is perhaps most clearly stated in his own words: "This (tentative) rule seems to rest on the fundamental mechanical law that the energy required to move a fluid (either liquid or gas) through a pipe or analogous conductor is proportional to the distance. Thus, to force water twice as far through a pipe line requires twice the force. According to this theory, doubling the spacing means doubling the distance the oil must be forced to the well, and inasmuch as the proportion of gas energy to oil is not increased, it would naturally be expected that the energy would be effective to only half the degree and, hence, result in only half the recovery, which accords with the facts." This justification, as indicated above, is unsound, due to the fact that flow through a reservoir was assumed to be analogous to flow through a pipe line (linear flow). It is also in error in the assumption that recovery efficiency is a direct function of energy consumption in the reservoir.

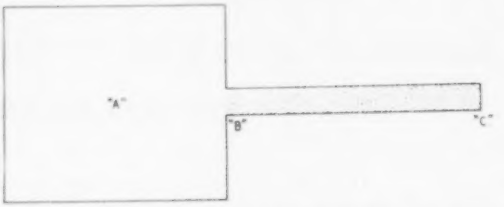

FIG. 1 — SIMPLIFIED FLOW SYSTEM FOR ILLUSTRATION OF ENERGY RELATIONS, CONSISTING OF CONSTANT VOLUME CHAMBER A, DISCHARGING THROUGH SAND PACKED COLUMN BC, TO OUTLET C.

The error of comparing flow through an oil reservoir to flow through pipe line has been pointed out repeatedly. The former is linear in geometry and is represented by parallel flow paths and by a constant cross sectional area available for flow, while the latter is near radial in geometry and is represented by converging flow paths and varying cross sectional area available for flow. Differences between the flow and energy consumption characteristics of linear and radial flow systems can be demonstrated quantitatively by the comparison of the integrated (steady state) form of the Darcy Equation for the two types of flow systems. This has been done by Miller and Higgins of the U. S. Bureau of Mines,[2] who show that, with ordinary well spacings and well bore diameters, doubling the spacing will result in a nine to 12 per cent increase in flow resistance and energy consumption. For a linear flow system, as used in Cutler's reasoning, the flow resistance and energy consumption would be doubled under the same circumstances. Thus, on the basis of the flow pattern alone, Cutler's theoretical justification of his rule should indicate the effect of well density on recovery efficiency to be approximately 10 per cent of what the rule provides and the data indicate.

Over and above the error of utilizing linear flow principles, Cutler's justification on the basis of energy relations relies upon the false assumption that recovery efficiency is inversely proportional to the energy utilized in overcoming flow resistance within the reservoir. His reasoning represents essentially a simple energy balance, in which the potential expansive energy initially present in the reservoir fluids is equated to the product of the number of barrels of oil to be recovered times the energy consumption of the flow system per barrel production.

$$E = NF \qquad (1)$$

where E = initial energy content of the reservoir
N = number of bbl of oil to be recovered
F = units of energy utilized per bbl to overcome flow resistance in the rock

or $$N = \frac{E}{F} \quad \ldots\ldots\ldots\ldots\ldots \quad (1\text{-A})$$

The energy balance so written is incomplete and its implications erroneous. It fails to distinguish between energy consumption within the system to overcome flow resistance and total energy removed from the system, i.e., energy voidage. Energy content of the produced fluids after they reach the well bore has been ignored completely and tacitly assumed to be zero under all circumstances. If we let H = the energy content per bbl of produced fluid after it reaches the well bore, the correct equation may be written.

$$(E_1 - E_2) = N(F + H) \quad \ldots\ldots\ldots \quad (2)$$

where subscripts 1 and 2 refer to initial and abandonment conditions, respectively. It is obvious from this expression that the recovery efficiency from a reservoir cannot be evaluated in terms of the energy utilized to overcome flow resistance in the system and that Cutler's logic, as represented by Equation 1, is invalid.

The true significance of energy relations in a producing reservoir becomes readily apparent upon application of an energy balance between the fluids remaining in the reservoir and those produced. Such an analysis indicates that recoveries cannot be expected to be directly related either to energy content of the reservoir fluids or to the manner in which that energy is utilized. Consider a constant flow system of the type illustrated in Fig. 1, which will be assumed to contain a homogeneous (single phase) compressible fluid, such as a gas or an under-saturated crude oil. Fluid is being produced isothermally through a sand packed tube, BC, to an outlet, C, by virtue of expansion of fluid within the chamber, A. The volume of fluid contained in the flow channel, BC, may be considered to be negligible. The energy content of the system at any time in its depletion history may be written as follows:

$$E = g \int_{v}^{v_{1a,t}} p\,dv = \frac{y}{v} \int_{v}^{v_{1a,t}} p\,dv \quad \ldots\ldots \quad (3)$$

where E = expansive energy content of fluids contained in the system, referred to atmospheric condition.

g = volume, at atmospheric conditions, of fluids contained in the system

p = pressure

v = relative fluid volume, at reservoir conditions, referred to volume at atmospheric conditions

y = volume of the system

For any particular fluid, the relative volume (v) is a function of pressure. The rate of change of energy content of the system with respect to pressure is expressed:

$$\frac{dE}{dp} = \frac{d}{dp}\left[\frac{y}{v}\int_{v}^{v_{1a,t}} p\,dv\right] \quad \ldots\ldots \quad (4)$$

The expression $\frac{dE}{dp}$ represents, of course, the energy voidage from the system per unit pressure drop, and is expressed as a function of the volume of the system, the pressure therein, and the pressure-volume characteristic of the contained fluid. The quantity of fluid within the system can be described in terms of the volume of the system, the pressure therein, and the pressure-volume characteristic of the contained fluid.

$$g = \frac{y}{v} \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

Differentiating with respect to pressure,

$$\frac{dg}{dp} = y\,\frac{d}{dp}\left(\frac{1}{v}\right) \quad \ldots\ldots\ldots \quad (6)$$

Combining Equations 4 and 6,

$$\frac{dE}{dg} = \frac{\frac{d}{dp}\left[\frac{1}{v}\int_{v}^{v_{1a,t}} p\,dv\right]}{\frac{d}{dp}\left(\frac{1}{v}\right)} \quad \ldots\ldots \quad (7)$$

The expression $\frac{dE}{dg}$ represents the energy voidage from the system per unit of production from the system, as a function of the pressure existing in the system and the pressure volume characteristic of the contained fluid. Note that the energy voidage per unit production is entirely independent of the dimensions of the system, the number of outlets, the flow resistance of the withdrawal system, or the rate of production.

The energy voidage of the system per unit production must be accounted for in terms of the energy consumption of the flow system, (F), and the energy content of the produced fluids, (H), per unit production. For a system containing a given fluid,

$$(F + H) = \frac{dE}{dg} = \phi\ (p) \quad \ldots\ldots\ldots \quad (8)$$

which indicates that the total energy voidage per unit of pro-

Table 1

Effect of Regional Migration Upon Recovery for Various Spacing Patterns

Case	1	2	3	4	5	6
Recovery—Bbls./Acre for 10-Acre Development	9,723	——	8,581	6,685	5,320	——
Recovery—Bbls./Acre for 20-Acre Development	——	6,630	——	——	——	4,784
Recovery—Bbls./Acre for 40-Acre Development	3,193	3,578	2,769	2,545	2,534	3,060
Recovery—Bbls./Acre Average	3,919	3,917	3,932	3,926	3,927	3,922
Recovery Ratio—Close to Wide Development	3.045	1.853	3.098	2.626	2.099	1.563
Recovery Ratio—Required by Cutler's Rule	2	1.414	2	2	2	1.414

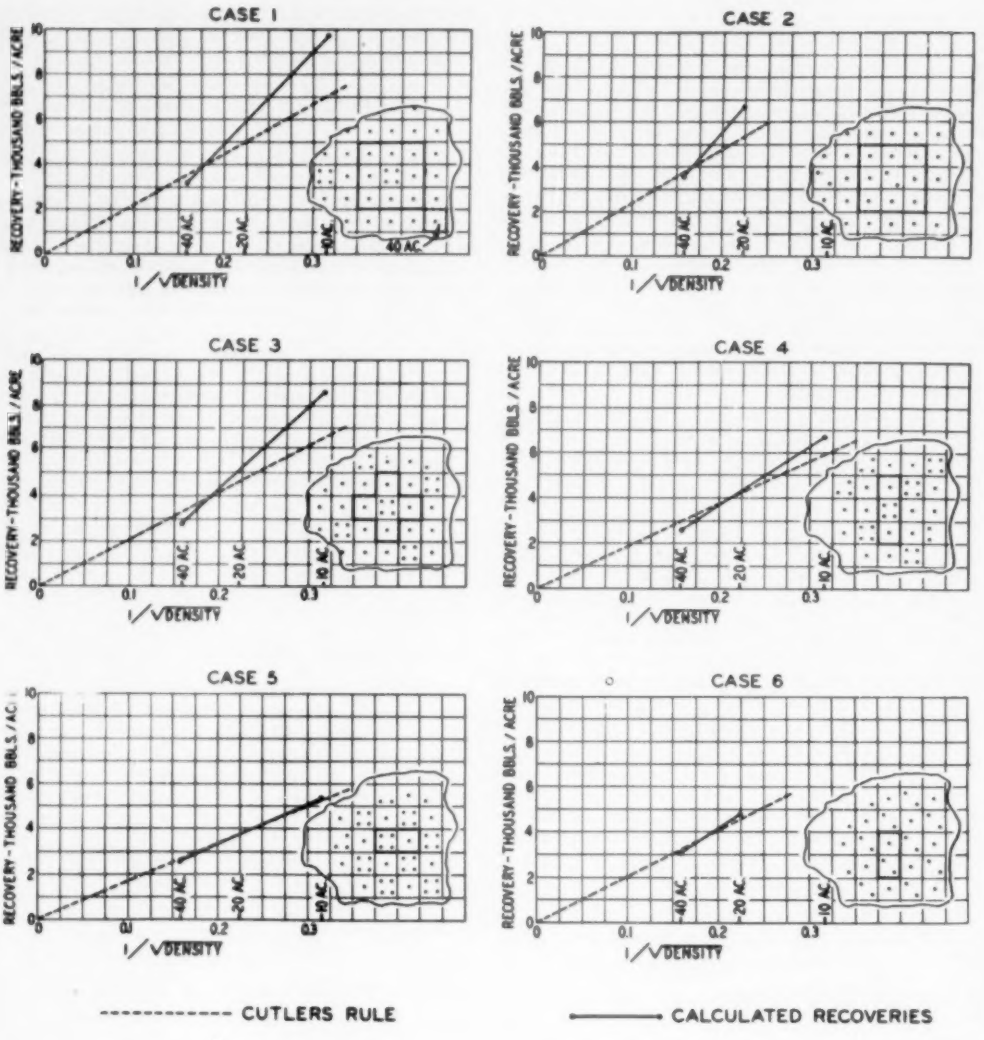

FIG. 2 — VARIATION IN RECOVERY WITH WELL DENSITY DUE TO REGIONAL MIGRATION FOR VARIOUS SYMMETRICAL SPACING PATTERNS.

duction is always equal to the sum of the quantities F and H but that the value of either is of no consequence to the total energy voidage per unit production, which is uniquely related to pressure and fluid characteristic. The energy voidage cannot be changed by altering the quantity of energy utilized to overcome flow resistance; such will only serve to alter by a like amount the quantity of energy to be produced with the fluids at the outlet of the system.

What, then, is the significance of energy relations in the flow system illustrated in Fig. 1? Actually, the energy to be voided from a system per unit production at any particular time, as expressed by Equation 7, will determine the maximum rate to which those fluids can be produced. The maximum flow rate from the system illustrated in Fig. 1 will exist when the outlet pressure is atmospheric and the energy content of the produced fluids, H, is equal to zero. The total energy voidage of the system $\frac{dE}{dg}$ will then be utilized to

overcome fluid friction in the rock. The value of this energy voidage per unit production will, therefore, determine the maximum rate at which the system can be produced at any particular time in its depletion history. The energy voidage per unit production will, therefore, determine, in the same fashion as the permeability, viscosity, dimensions and geometry of the flow system, the maximum production rate at any time from the system. It will not, as such, determine the quantity of fluid to be recovered.

Although the relations expressed in Equations 3 through 8 have, for the purpose of simplification, been derived for the system diagramed in Fig. 1, they will apply to a continuous porous system with negligible error provided that average pressures be utilized.

Three generalizations with regard to energy relations of a flow system producing expansible fluids by virtue of their expansion alone are in order:

1. Potential expansive energy content of the system is determined uniquely by the volume of the system, the pressure, and the pressure-volume characteristic of the contained fluid.
2. Energy voidage per unit production is determined uniquely by the pressure and the pressure-volume characteristic of the fluid and cannot be altered by varying the dimensions of the system or the flow rate.
3. The energy voidage per unit production, together with the geometry of the flow system, its permeability and the viscosity of the fluid, will determine the maximum productive capacity of the system.

The discussion of energy relations presented above is confined to homogeneous fluid (single phase) depletion type systems. Cutler's Rule was developed and intended to apply to depletion type oil reservoirs, wherein two phases (oil and gas) ordinarily co-exist and are produced simultaneously. The fluid content of a depletion type oil reservoir can be arbitrarily broken into two components: that part of the fluid which will exist in the liquid phase at stock tank conditions and that part which will exist in the vapor phase at stock tank conditions. The potential expansive energy of that part of fluid which will exist in the liquid phase at stock tank conditions is very small compared to that of the portion which will exist in the vapor phase. The potential expansive energy of the portion which will exist in the liquid phase can for all practical purposes be ignored and the energy content of the system considered to exist solely in the form of free and solution gas.

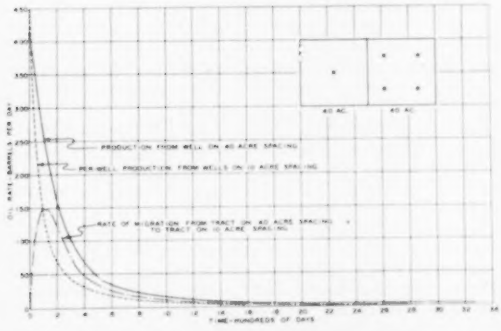
40 AC.
40 AC.
PRODUCTION FROM WELL ON 40 ACRE SPACING
PER WELL PRODUCTION FROM WELLS ON 10 ACRE SPACING
RATE OF MIGRATION FROM TRACT ON 40 ACRE SPACING TO TRACT ON 10 ACRE SPACING
TIME-HUNDREDS OF DAYS

FIG. 3 — CALCULATED PRODUCING RATES AND MIGRATION RATES FOR THE SPACING PATTERN ILLUSTRATED IN CASE 5, FIG. 2.

Under these circumstances, the generalizations developed with regard to the energy relations for a homogeneous fluid system can be expected to hold between the reservoir and the well bore for a depletion type oil reservoir when applied specifically to that portion of the reservoir fluid which would exist in the vapor phase at atmospheric conditions. It follows that the energy relations at any particular time in a depletion type oil reservoir cannot be altered except by altering the producing gas-oil ratio or injecting extraneous fluids.

As pointed out previously, the logical explanation for the relation observed by Cutler and others between recovery and well density for wells in the same field is regional migration. The requirements which Cutler placed upon his data with regard to the utilization of wells of approximately the same size, completed at approximately the same time, in areas of uniform pay thickness and that interference existed between wells, is such that regional migration from the areas of wider spacing to areas of closer spacing is inevitable. The more densely developed areas will be subject to more rapid withdrawal rates per acre and per acre foot of pay and will be subject to a more rapid rate of pressure decline than the areas of wider spacing. This situation can only result in the development of pressure "sinks" around the areas of dense development and pressure "highs" around the less densely drilled areas, which in turn will result in migration from the high to low pressure areas or from the areas of wider spacing to areas of closer spacing. The influence of migration upon the per acre recoveries of tracts drilled to different densities in the same pool has been recognized by many writers, including Miller and Higgins[2] who state that at least part of the increased production credited to more densely drilled tracts must be attributed to regional migration.

Calculations intended to evaluate quantitatively the effect of migration under conditions of varying well densities have been prepared for a typical set of reservoir conditions. These calculations have been prepared for six geometrical configurations of tracts of different well densities representing portions of six symmetrical spacing patterns. Reservoir conditions underlying the tracts were assumed to be identical in order to duplicate the conditions which Cutler strove to find, and all wells were assumed to be opened to production at the same time and produced to capacity until a limiting economic rate of three bbl per well per day was reached. The performance of the six systems was derived by a step-wise solution combining simultaneously the depletion drive behavior, as outlined by Muskat,[3] and well production and regional migration rates in terms of Darcy's Law. Since regional migration operates in a system of complex geometry (i.e., not simple radial or linear geometry), a constant for insertion in the Darcy equation to reflect the flow pattern which the migrating oil would assume was evaluated for each of the six cases by means of the electric analyzer.

These calculations are based upon the assumption that the variation of recovery efficiency with well spacing will be negligible; therefore, the entire difference in recovery as reflected thereby must be attributed to regional migration. The results of these calculations are presented in Fig. 2 and in Table I. The points representing actually calculated values in the graphs on Fig. 2 are connected with straight lines solely for the purpose of comparison with the slope of the line representing Cutler's Rule for the various spacing patterns. Fig. 3 illustrates the rates of production and migration as a function of time for Case 5. Note that the variation in per acre recoveries with well density from migration alone is in each instance somewhat more severe than that predicted by Cutler's Rule. These data lead to the conclusion that the well density-

recovery relation observed by Cutler and by others on intra-field recovery comparisons might very easily have resulted from migration alone, even if there were no variation in recovery efficiency with well density.

Consideration of the variables at work in the preceding calculations points to the conclusion that the effect of the magnitude of the permeability of the rock, together with other factors, such as viscosity, which determine the productivity index of the wells, will not affect appreciably the relative recoveries for a given geometrical arrangement of wells. This is to be expected because the same factors which govern the ability of the wells to produce oil also govern the ability of the oil to migrate. It is believed that any reasonable set of depletion type reservoir conditions, under the specified requirement of simultaneous well completion, unrestricted production, uniform permeability, porosity, and pay thickness, would yield relative recoveries for the geometrical patterns analyzed of the same order of magnitude as those shown in Fig. 2. Under otherwise similar conditions artificial restriction of producing rates would, if allowables were on a per-well basis, increase the severity of migration, the per-well recovery approaching equality (per acre recoveries inversely proportional to well density) if the allowables were very small. However, artificial restriction with allowables on an acreage basis would prevent migration completely during the prorated period; migration would be confined to the period of decline and total migration over the life of the system reduced.

The preceding considerations indicate strongly that the variations in recovery with well density for intra-field comparisons can be attributed primarily to regional migration and that Cutler's Rule cannot be applied in evaluating field-wide recoveries. The explanation of such variation in terms of energy relations which would attribute the different recoveries to variations in recovery efficiency with well density has been refuted. One fact is quite apparent; the relation between well density and recovery efficiency cannot be isolated by means of intra-field comparisons. Data obtained from intra-field comparisons are of no real significance with regard to the effect of well density upon recovery efficiency.

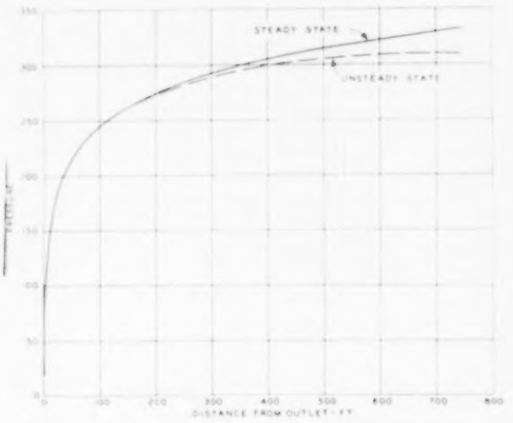

FIG. 4 — COMPARISON OF STEADY AND UNSTEADY STATE PRESSURE DISTRIBUTION IN RADIAL FLOW SYSTEM PRODUCING A SLIGHTLY COMPRESSIBLE FLUID AT EQUAL RATES.

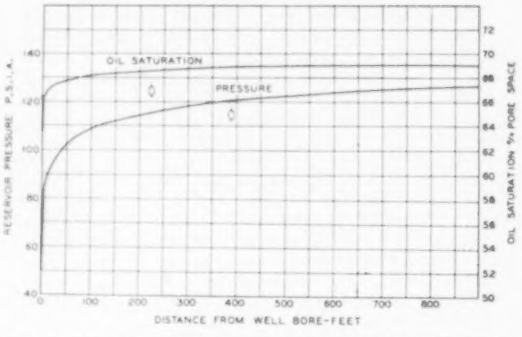

FIG. 5 — CALCULATED PRESSURE AND OIL SATURATION DISTRIBUTION AT ABANDONMENT. $K = 15MD$.

FIELD-WIDE COMPARISONS

Since the effect of regional migration makes evaluation of the relation between well density and recovery efficiency impossible by means of intra-field comparisons, it appears that the relation can be isolated from actual production data only by comparing in their entirety the recoveries from different fields developed to different well densities. Several investigators have attempted to evaluate the relation between density and recovery efficiency by this method. Two somewhat different techniques for evaluating the relation from field-wide data are possible, one consisting of the direct comparison of recoveries from two or more fields which are identical in all respects except well spacing; the other consisting of a statistical analysis of a large number of fields for the purpose of developing a "trend" between recovery efficiency and well density.

The first method, consisting of direct comparison of recoveries from fields of identical reservoir charateristics but different spacings, is subject to severe practical limitations due to the difficulty of finding two or more fields which are known to be identical in all respects other than well spacing, which might affect recovery efficiency, and in which basic reservoir data are of sufficient accuracy to permit close evaluation of the recovery efficiencies in each. An example of the uncertainties of this approach is available in the analyses by Clark, Tomlinson and Royds[4] and by Vietti, Mullane, Thornton and vanEverdingen[5] of data presented by Hill and Guthrie[6] on the Mexia-Powell Fault Line Fields of Texas. The two analyses resulted in exactly contrary conclusions as to the effect of well density upon recovery efficiency by use of the same data. An impartial observer must conclude that the data were of insufficient basic accuracy to permit a definite conclusion either way.

The second method for evaluating the well density-recovery efficiency relation by means of field-wide comparisons is the statistical analysis, represented in the literature by the work of Craze and Buckley.[7] This analysis reflected no significant variation of recovery efficiency with well spacing for a group of approximately 70 water drive fields. Although the basic data utilized by these authors may not have been of sufficient accuracy to detect a relatively small variation in recovery efficiency with well density, the fact that the effect of certain other reservoir factors, such as oil viscosity, did show up indicates that any pronounced variation in recovery efficiency with well density would have been reflected in the analysis. A variation in recovery efficiency with well density of the order

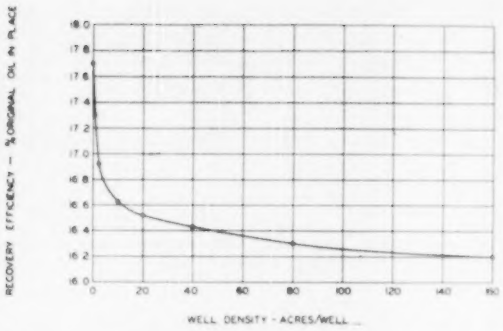

FIG. 6 — CALCULATED VARIATION IN RECOVERY EFFICIENCY WITH WELL DENSITY.

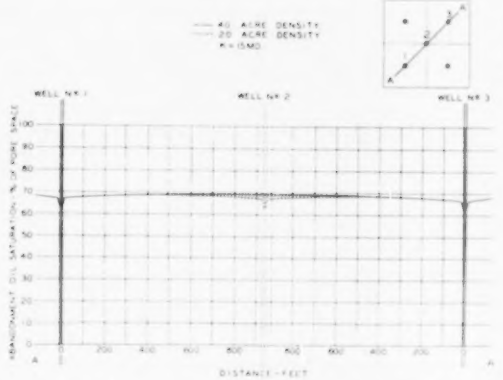

FIG. 7 — OIL SATURATION DISTRIBUTION AT ABANDONMENT CONDITIONS.

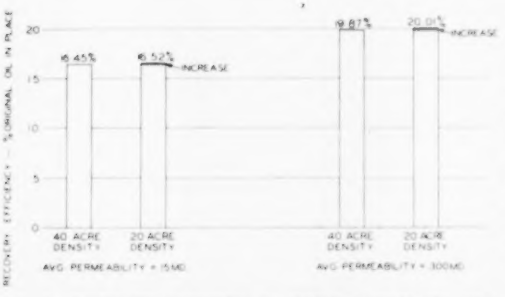

FIG. 8 — CALCULATED VARIATION IN RECOVERY EFFICIENCY WITH WELL DENSITY AND PERMEABILITY.

of magnitude of Cutler's Rule would most assuredly have appeared in Craze and Buckley's analysis.

WELL SPACING IN TERMS OF RESERVOIR MECHANICS

The relation between well density and recovery efficiency is inherently incapable of being isolated by means of intra-field comparison. Due to practical limitations, the relation has not as yet been quantitatively developed from field-wide comparisons. Any relation which does exist must have some logical basis in terms of reservoir mechanics and should be apparent in the mechanism of fluid displacement from porous rock. From a consideration of the currently accepted concepts of the mechanism of fluid displacement in porous rock and of the principles governing the behavior of oil reservoirs, it appears that no appreciable variation in recovery efficiency with well density is to be expected. The results of a quantitative analysis for a particular set of depletion type reservoir conditions indicate that the variation in recovery efficiency with well density will be extremely small. Consideration of the variables at work indicates that the same general situation may be anticipated for any reasonable set of depletion type reservoir conditions, provided that the reservoir is continuous between wells.

It is apparent that the relation between well density and recovery efficiency will be a function of the saturation distribution throughout the well drainage radius at the time the well must be abandoned. Conversely, the well spacing relation can be evaluated quantitatively in terms of the saturation distribution at abandonment with respect to distance from the well bore. Evaluation of saturation distribution in a depletion type oil reservoir requires that the entire production history of the system be reproduced. The rigorous reproduction of the entire history of a two-phase system of finite dimensions producing in the unsteady state involves the solution of a non-linear differential equation of such complexity that it has not been accomplished to date. It is possible, however, to reproduce approximately the production history of such a system and the abandonment saturation conditions in such a system by means of a judiciously chosen set of simplifying assumptions. Approximate solutions of this type have been advanced by at least three writers,[8,9,10] which although slightly different in the method of attack, arrive at approximately the same results. These analyses are all based upon the proposition that the unsteady state performance can be reproduced closely by means of a succession of steady states, utilizing the depletion drive theory advanced by Muskat[5] and others for vanishing pressure gradients and the Darcy equation. Actual calculations consist of the construction of a series of steady state solutions, both in regard to time as the reservoir as a whole undergoes depletion and in regard to distance from the well bore at any particular time.

Consideration of the geometry of a near-radial flow system, wherein the majority of the pressure drop occurs in the immediate vicinity of the well bore, and wherein the bulk of the producing formation lies near the outer boundaries of the system,* leads to the conclusion that the composition of the flowing stream will, in a depletion type oil reservoir and in the absence of transient conditions, be relatively constant from the well bore to the extreme radius of drainage, and will be closely consistent with the composition of the production from that part of the rock which lies near the outer limits of the drainage radius. This generalization is derived from the fact that the area from which most of the produced fluids

*This situation is a reflection of the fact that the volume of a cylindrical solid is proportional to the square of its radius; thus only one-quarter of the volume of such a solid lies within the inner half of its radius.

originate is an area of small pressure gradients in which the depletion drive theory for vanishing pressure gradients can be expected to hold very closely (Fig. 4). The area near the well bore, where large pressure gradients exist, contribute very little to the well efflux and acts primarily to transmit fluids produced from outlying elements. Saturation conditions in areas near the well bore are determined, therefore, to a much greater extent by the producing gas-oil ratio of the outlying elements than by the depletion drive theory for vanishing pressure gradients.

Calculations intended to evaluate abandonment saturation distribution, based upon the approximation of constant total gas-oil ratio throughout the drainage radius as determined by pressure and saturation conditions in the outlying elements, have been prepared for two particular sets of reservoir conditions. The permeability of the rock was taken to be 15 millidarcys in one instance and 300 millidarcys in the other; all other reservoir factors were identical in both calculations. The economically limiting (abandonment) oil producing rate was assumed to be three bbl per well per day. The results of these calculations are presented in Figs. 5 through 9. Fig. 5 represents the calculated variation in pressure and oil saturation at an abandonment oil production rate of three bbl per well per day for the set of calculations using a permeability of 15 millidarcys. Abandonment oil saturation gradients are very small and the recovery efficiency practically the same at all distances from the well bore except for a small saturation sink in the immediate vicinity of the well bore. The effect of these saturation gradients in terms of recovery effiiency for the K = 15 md. calculation is illustrated in Fig. 6. Note that there is very little variation in recovery efficiency with well density except for very close spacing. Fig. 7 is included only for illustrative purposes, showing saturation and pressure distribution at abandonment in the area surrounding three wells. Under the conditions of saturation distribution outlined, it is apparent that the only effect with regard to recovery efficiency of drilling the center well will be to develop a small saturation sink in the immediate vicinity of that well. Fig. 8 represents the relative recovery efficiencies for permeability values of 15 millidarcys and 300 millidarcys, all other reservoir conditions being identical. It is interesting to note that the effect of permeability is to cause some variation in recovery efficiency. However, the drilling of additional wells will have no greater effect upon recovery efficiency in the low permeability situation than in the high permeability situation. In either instance, however, the effect of number of wells upon the rate of production from a given reservoir is appreciable, provided that the wells are produced at capacity or that allowables are on a per well basis. Fig. 9 represents the entire producing history of a representative 40-acre tract under the assumed reservoir condition (K = 15 md.) for a 20-acre development and for a 40-acre development.

The basic reasons for the flat saturation gradients and small effect of well density upon recovery efficiency in a continuous depletion type reservoir are:

1. The radial geometry of the drainage pattern.
2. The mechanism of oil displacement by gas.

Indeed, the authors are unable to conceive of a set of conditions under radial drainage and consistent with the mechanism of oil displacement by gas under which the steep saturation gradients necessary for an appreciable effect of well spacing on recovery efficiency could exist. If an appreciable effect does exist, the currently accepted concept of fluid displacement is in need of radical revision.

An analysis of the well spacing problem in terms of abandonment saturation conditions is obviously inapplicable when

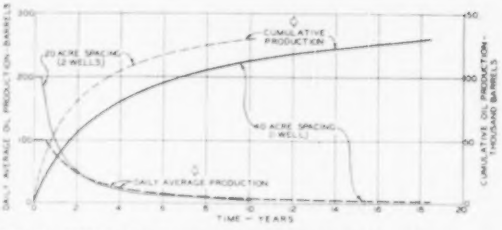
CUMULATIVE PRODUCTION
20 ACRE SPACING (2 WELLS)
40 ACRE SPACING (1 WELL)
DAILY AVERAGE PRODUCTION
DAILY AVERAGE OIL PRODUCTION - BARRELS
CUMULATIVE OIL PRODUCTION - THOUSAND BARRELS
TIME - YEARS

FIG. 9 — EFFECT OF WELL DENSITY UPON PRODUCTION RATES FOR A 40-ACRE TRACT. K = 15MD.

a lenticular condition exists throughout the producing reservoir; that is, when the pay zone is not continuous between the producing wells. In order to obtain maximum recovery from a reservoir composed of separate lentils, it is necessary that at least one well bore penetrate each and every separate lentil. The generalizations developed above with regard to depletion drive reservoirs are, therefore, strictly limited to those instances in which continuous communication between wells exists.

The depletion drive theory, together with the well spacing calculations derived therefrom, is based upon the assumption that gravitational segregation of fluids within the rock is negligible in the time interval required to produce the reservoir. Gravitational segregation is known to be appreciable in many depletion type fields, particularly those of high permeability, and the depletion drive theory together with the well spacing calculations of the type illustrated above cannot be expected to hold quantitatively. However, since the gravitational influence is not related to the distance which a particular segment of the rock lies from the well bore and since drainage must still occur through a radial system, it is not believed that the presence of the gravitational segregation will itself cause an appreciable variation in recovery efficiency with well density.

Table II
Completion Pressure Data — Field "B"

Well No.	Date of Test	*Completion Pressure PSIA	Pressure Decline Prior to Completion PSIA
1	4-29-46	2,021 (Field Orig.)	0
2	11-4-47	1,982	39
3	2-5-48	1,945	76
4	6-29-48	1,807	214
5	8-10-48	1,787	234
6	8-16-48	1,812	209
7	8-20-48	1,653	368
8	8-23-48	1,729	292
9	8-27-48	1,685	336
10	8-29-48	1,735	286
11	9-8-48	1,343	678
12	9-9-48	1,723	298
13	9-13-48	1,868	153
14	9-15-48	1,218	803
15	9-16-48	1,730	291
16	9-22-48	1,594	427
17	9-24-48	1,565	456
18	10-6-48	1,739	282
19	10-15-48	1,631	390

*Completion pressures are maximum build-up bottom-hole pressures taken immediately after initial potential tests.

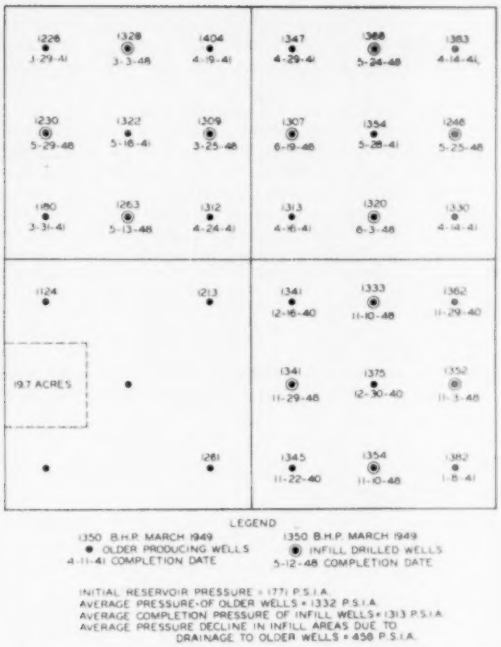

FIG. 10 — COMPARISON OF COMPLETION PRESSURES OF LATER-DRILLED INFILL WELLS AND OLDER WELLS — FIELD A.

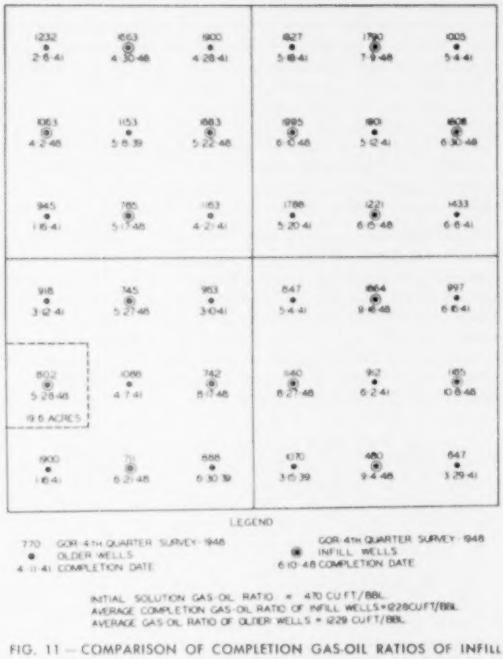

FIG. 11 — COMPARISON OF COMPLETION GAS-OIL RATIOS OF INFILL WELLS WITH GAS-OIL RATIOS OF OLDER WELLS IN A DEPLETION TYPE RESERVOIR — FIELD A.

The application of depletion drive theory to actual reservoir rocks has been questioned by some, due to the fact that such rocks are not uniform with respect to permeability and porosity as must be assumed for quantitative calculations. It seems reasonable to expect, however, that if the recovery efficiency does not vary appreciably with distance from the well bore for any reasonable set of conditions of uniform permeability and porosity (as indicated to be the case), the variations in recovery efficiency in a heterogeneous system will not vary appreciably for any particular segment of rock with its distance from a well bore.

The well spacing problem in water drive reservoirs has not been the cause of as great concern as in depletion type reservoirs due to the superabundance of expansive energy and displacing fluid furnished by encroaching water. A water drive reservoir is ordinarily abandoned when the water-oil ratio reaches an economically limiting value. The recovery efficiency, therefore, depends upon the average oil saturation in the reservoir at which limiting water-oil ratios can be expected, and a variation in recovery efficiency with well spacing must be the result of reaching the limiting water-oil ratio at different average oil saturations with different well spacings. There is no reason to believe that the variation in recovery efficiency with well density on a uniform pattern will be appreciable; however, abandonment oil saturation conditions with respect to distance from the well bore in a water-drive reservoir cannot be sensibly generalized in terms of reservoir mechanics, due to the fact that abandonment saturations surrounding any particular well depend preponderantly upon the sand and well bore conditions peculiar to that well. It is readily apparent that the recovery efficiency in a water drive reservoir will depend considerably upon well location; strategic location of wells at or near the top of the reservoir or of separate sand stringers is essential for maximum recovery.

CONTINUITY

Since it is indicated that the effect of well density upon recovery efficiency for reasonable variations in well density is small in continuous reservoirs, and since it is obvious that infill wells will obtain additional oil in a lenticular reservoir, it appears that the well spacing problem in a particular field can be resolved into the problem of determining whether or not the reservoir is continuous. Fortunately, engineering and production data are capable of yielding a positive answer as to the presence or absence of continuity in most reservoirs.

There is no doubt as to the existence of continuity between wells in a field in which an effective water drive exists. The observation of the results of water influx in terms of pressure behavior is in itself a reflection of continuity and freedom of migration of fluids throughout the reservoir.

In depletion type fields, the presence or absence of continuity must be established from certain specialized testing techniques. Depletion drive theory indicates that the pressure existing in the inter-well area should be very closely equal to the maximum shut-in bottom-hole pressure of the currently

producing wells. Furthermore, it is to be expected that the gas-oil ratio of an infill well completed between old producing wells will be of the same magnitude as those existing at the same time in the older offset wells and that the well productivity should be approximately equal. The drilling of an infill well into an area which has been produced by other wells for a considerable time provides, therefore, an excellent opportunity for observing the pressure and stage of depletion existing in the inter-well area and of determining whether or not the inter-well area is being adequately drained from the old producing wells.

If an infill well between older wells on any certain spacing pattern exhibits a pressure upon completion equal to the virgin reservoir pressure, that fact constitutes positive evidence that the inter-well area has suffered no drainage from the offset wells and that a lenticular condition exists in which the additional wells can be expected to recover appreciable additional oil. The exact quantity of additional oil to be recovered cannot be evaluated, because it depends upon the size and number of previously untapped lentils which the new well happens to penetrate.

If, on the other hand, an infill well immediately upon completion exhibits a bottom-hole pressure consistent with the current shut-in bottom-hole pressure of older offset wells and if the gas-oil ratio and other producing characteristics of the well are similar to those of the offset wells, it can reasonably be concluded that the inter-well area is at approximately the same stage of depletion as the areas surrounding the older wells. The inter-well area has been and is capable of being drained by the offset wells and an appreciable increase in ultimate recovery cannot be expected. The infill well will simply deplete reservoir space which would have otherwise been depleted by the older wells and recover oil which would otherwise have been recovered by the older wells on wider spacing. The productivity of the infill well should furthermore be of the same magnitude as that currently existing in the older wells and considerably below the initial potential of the early completions in the field. Productivity data, however, must be used with care due to normal variation in permeability and pay thickness within the reservoir, and due to the effect of transient conditions if the new well has not completely stabilized. Frequently, also, the condition of the hole is considerably better in a new well than in the old wells, resulting in productivities which at first glance may yield an erroneous impression. Several examples of actual field data, including initial completion pressures, gas-oil ratios, and well productivities of the type required to indicate whether or not continuity exists between wells are presented in Figs. 10 through 12 and in Table II.

Continuity in depletion gas drive reservoirs can also be determined by means of planned interference tests where pressure measurements are taken on a shut-in well surrounded by producing wells. Since the production from the shut-in well during the test period is zero, any pressure drop observed in the shut-in well can only be accounted for by movement of fluids away from that area due to the production of surrounding wells. The time required to conduct such interference tests is dependent upon the build-up period required for the shut-in well to reach maximum build-up pressure and the average rate of reservoir pressure decline in the area of the test. The time required to conduct such tests is usually lengthy, except where high rates of production are maintained or where the expansibility of the reservoir's fluids is small, as in an undersaturated reservoir. Care must be taken in such tests to allow sufficient time for the average reservoir pressure to decline a measurable amount; otherwise, the results may be subject to misinterpretation. Fig. 13 presents the results of a test in a

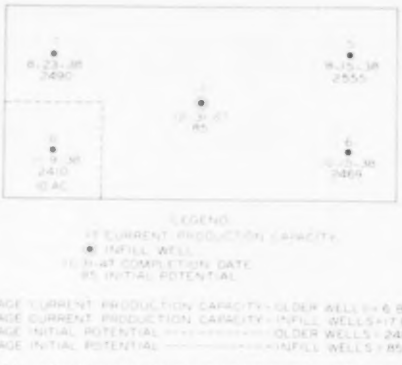

FIG. 12 — COMPARISON OF PRODUCTIVITY OF INFILL WELL WITH OLDER WELLS IN A DEPLETION TYPE RESERVOIR — FIELD D.

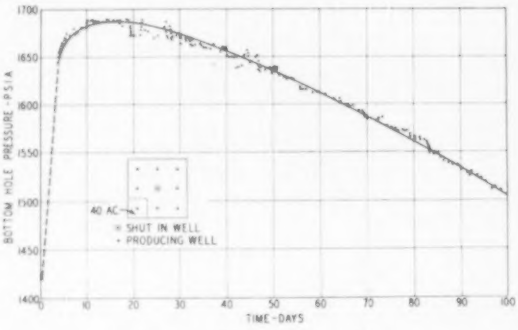

FIG. 13 — INTERFERENCE TEST — FIELD B.

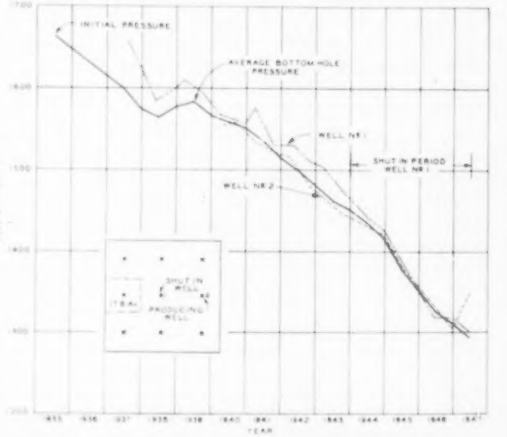

FIG. 14 — PRESSURE PERFORMANCE OF A SHUT-IN WELL IN A GAS DRIVE FIELD — FIELD C.

reservoir containing an under-saturated crude in which appreciable pressure drop occurred over a fairly short period of time. Fig. 14 reflects the behavior of a shut-in well over a longer period of time in a reservoir producing fluid below bubble point pressure.

Data of the type required to indicate whether or not continuity exists are available to the authors on a large number of fields. These data indicate continuity to exist in most reservoirs and that lenticular conditions are the exception. In most instances, therefore, the effect of well spacing upon recovery efficiency can be expected to be very small. A number of instances have come to the attention of the authors in which actual pressure, gas-oil ratio, and productivity data indicated communication to exist, but in which geological correlation of porous zones in the various wells was not possible. The presence or absence of continuity must be proven by means of behavior which is the direct result of continuity; in particular, pressure behavior. Speculation as to the presence or absence of continuity between wells on the basis of geological data alone is extremely risky.

CONCLUSIONS

The following conclusions appear to the authors to be in order:

1. Justification of an appreciable variation in recovery efficiency with well spacing in terms of energy relations is not valid.
2. Observed variations in actual recoveries with well density between different leases in the same field can be attributed largely to regional migration.
3. Comparison of field-wide recoveries, though representing a fundamentally sound approach, has not as yet furnished a positive answer to the well spacing question.
4. Consideration of the principles of reservoir mechanics indicates that the variation in recovery efficiency with well density will be very small for a continuous reservoir.
5. The well spacing problem in most fields can be resolved, in terms of whether or not continuity exists, by means of properly planned and executed testing programs.

ACKNOWLEDGMENT

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APPENDIX

Pressure and saturation distribution around a well bore in a depletion-drive system, from which recovery efficiency as a function of well spacing can be evaluated, was approximated as shown in Figs. 5 through 9. The methods of arriving at these approximate solutions were chosen upon the basis of the logic expressed in the text, in which it was concluded that the total composition of the flowing stream (liquid *and* vapor phases) at any particular time in the history of the system can be expected to:

1. Be approximately the same from the extreme radius of drainage to the well bore.
2. Be controlled by the composition at the extreme radius of drainage whereat the behavior of the system can be accurately predicted by the depletion-drive concept, due to the fact that vanishing pressure gradients exist at that point.

The relations developed may be derived as follows:
For a given element of reservoir rock,

$$(1)\quad GOR = F\,(K_o/K_g) + r_v$$

$$(2)\quad F = \frac{\mu_g}{\mu_o} \times \frac{14.7}{p} \times \frac{5.61}{Z} \times \frac{520}{T_v}$$

Also,

$$(3)\quad q_o = \frac{7.073\ Kt\ K_o/K}{\mu_o \beta} \cdot \frac{rdp}{dt}$$

Rearranging (3),

$$(4)\quad q_o \int_{t_o}^{t_w} \frac{dt}{r} = \frac{7.073\ Kt\ K_o/K}{\mu_o \beta} \int_{p_o}^{p_w} dp$$

By the logic expressed above and in the text,

(5) Let $GOR = \phi\ (p_o)$ (from material balance)

Assuming uniform contribution of various elements to the total flow stream into the well bore (in the absence of transient conditions),

$$(6)\quad q_o = Q_o \left(1 - \frac{r^2}{r_e^2}\right) \text{ (Approximately)}$$

From (2),

$$(7)\quad F = \phi\ (p)$$

Also,

$$(8)\quad r_v = \phi\ (p)$$

Substituting (5), (7), and (8) in (1), it follows that, for a given value of p_e

(9) $K_g/K_o = \phi\ (p_e,\ p)$

From relative permeability relations, for a given s_w,

(10) $K_g/K_o = \phi\ (s_l)$

And

(11) $K_o/K = \phi\ (s_l)$

Therefore,

(12) $K_o/K = \phi\ (K_g/K_o)$

Combining (9) and (12)

(13) $K_o/K = \phi\ (p_e,\ p)$

Also,

(14) $\mu_o = \phi\ (p)$

(15) $\beta = \phi\ (p)$

Substituting in (4),

$$(16)\quad Q_o \int_{r_w}^{r_e} \left(1 - \frac{r^2}{r_e^2}\right) \frac{dr}{r} = 7.073\ KT \int_{p_w}^{p} \frac{K_o/K}{\mu_o \beta}\ dp$$

This relation must be evaluated (integrated) graphically from r_e to r_w, and intermediate points to obtain p as a function of r. Since, at abandonment condition, Q_o is determined by economic factors and p_w by physical factors, value of these variables must be fixed in evaluating pressure and saturation distribution at abandonment conditions. The total gas-oil ratio, however, is chosen as a function of p_e. The solution of the relation therefore becomes a trial and error proposition, in which a value for p_e is arbitrarily chosen and p_w evaluated for the desired Q_o until a value of p_e has been found which will yield the desired value of p_w. Elimination of expression (6) and substitution of Q_o directly for q_o will result in only a slight modification of the calculated pressure distribution.

Once the pressure distribution has been determined, the oil saturation and oil in place at abandonment, as a function of r, can be evaluated.

Since s_o is a function of liquid saturation (for a given s_w), it follows from (16) that

(17) $s_o = \phi\ (K_o/K) = \phi\ (p_e,\ p) = \phi(r)$

(18) Oil in place/unit pore volume $= s_o/\beta$

$$(19)\quad \text{Abandonment oil in place} = 2\pi tf \int_{r_w}^{r_e} \frac{s_o}{\beta}\ r dr$$

$$(20)\quad \text{Oil Recovery} = \pi tf \left[\frac{(1 - s_w)}{\beta_i}\ (r_e^2 - r_w^2) - 2 \int_{r_w}^{r_e} \frac{s_o}{\beta}\ r dr\right]$$

NOMENCLATURE

ϕ	=	Symbol denoting "function of"
GOR	=	Total gas-oil ratio (free and solution gas)
p	=	Pressure
p_e	=	Pressure at the extreme radius of drainage
p_w	=	Pressure at the well bore
r	=	Radius, distance from the center of the well bore
r_w	=	Well bore radius
K	=	Permeability
K_o	=	Effective permeability to oil
K_g	=	Effective permeability to water
t	=	Pay thickness
μ_o	=	Oil viscosity
μ_g	=	Gas viscosity
Z	=	Compressibility factor of free gas
β	=	Reservoir volume factor of oil phase at any pressure, p
β_i	=	Reservoir volume factor of oil phase at initial pressure
q_o	=	Instantaneous rate of flow at any radius, r
Q_o	=	Rate of flow into the well bore (at r_w)
s_o	=	Oil saturation
s_w	=	Connate water saturation
s_l	=	Liquid saturation (oil plus water)
T_R	=	Reservoir temperatures
f	=	Fractional porosity

Oil And Gas Developments In Arkansas During 1949

By DONALD K. MACKAY,* Member AIME

The new oil and gas fields together with extensions in depth and area to old fields, that were discovered in Arkansas during 1949 compared favorably in number and size with the discoveries made annually in the state during the past few years. Before describing the oil and gas developments in some detail, the important new production found in 1949 is mentioned briefly. The new fields are Pine Tree and Spottsville in Columbia County and Loutre Creek in Union County. The Warnock Springs extension, Columbia County, is either a new field on the same anticlinal trend as Warnock Springs or a prolongation of the latter. The Stephens-Curry extension in Quachita County which includes several new oil reservoirs is regarded by some as a new field but may also be considered to be a faulted segment of the Stephens Field which is the classification used in the present review.

A new reservoir discovered during the year on the east edge of the Stephens Field (Quachita County), namely, the Hogg sand pool, although small in area, added several million bbl of recoverable oil to the reserves of the state. Of lesser importance were a number of new reservoirs found in the following fields: Atlanta (Columbia County), Buckner (Columbia and Lafayette Counties), Gum Creek (Quachita County), Hillsboro (Union County), Lewisville-West (Lafayette County), Village (Columbia County), and Wesson (Quachita County). Extensions were also made during the year to old producing reservoirs in a number of fields, namely: Bear Creek (Union County), Cairo (Union County), Hibank (Union County), Mc Kamie-Patton (Lafayette County), Sandy Bend (Union County) and Urbana (Union County).

Two deep tests drilling in South Arkansas as the year ended developed important new oil production. One of these, C. H. Murphy and Co. #1 Gregory, a "wildcat" bottomed at 9,500 ft in S E ¼ S W ¼ Sec. 25, T. 19 S., R. 18 W., Union County, became the discovery well of the Tubal Field. The other well, C. H. Murphy and Co. #1 Pepper, drilled to 7,922 ft in the Catesville area of the South El Dorado Field, Union County, encountered the first deep, commercial production in this shallow field which has yielded oil and gas since 1920. Although both C. H. Murphy and Co. tests were recognized as discoveries in 1949 they were not completed until 1950 and are, therefore, classified as discoveries in 1950 and not described in the present review.

In the dry-gas producing region of Northwest Arkansas two new fields were found in 1949 following a lapse of several years without a discovery. The new fields are the Cecil Field, Franklin County, and Rudy Field, Crawford County. White Oak Field in Franklin County was extended in old producing zones by wells drilled during the year.

A total of 359 wells were drilled in Arkansas during 1949. Ninety-five of these were "wildcats" of which six became discovery wells of new fields. The remaining 264 wells were drilled in the fields of the state and of these 186 became producers and 78 were dry holes. In addition, 71 old wells were recompleted during the year. Approximately 95 per cent of the drilling activity in the state during the year took place throughout South Arkansas and only five per cent in North Arkansas, mainly in the dry-gas producing region of Northwest Arkansas.

The review of oil and gas development in the state during 1949 that follows, summarizes briefly: the number of drilling blocks; geophysical prospecting; oil, gas and condensate production; pressure maintenance and other secondary recovery projects; as well as information on new fields, extensions in depth and area (new reservoirs) and in area only (to old reservoirs). The new developments are described under two headings: (1) South Arkansas and (2) Northwest Arkansas.

SOUTH ARKANSAS

Fifty-six fields in South Arkansas produce oil or gas and condensate from rocks of Cretaceous or Jurassic age and most of them are productive from multiple zones. The shallower fields lie on structural terraces or the high sides of faults and the deeper fields extend along anticlines.

At the beginning of 1949 approximately 76 large drilling blocks remained to be tested in South Arkansas but the number of small blocks brings the total to about 283. During the year 67 additional drilling blocks were taken. 79 blocks were condemned by wells drilled during the year and 5 blocks proved productive. Approximately 266 large and small drilling blocks remained to be tested at the end of the year.

Distribution of geophysical exploration according to counties is indicated on an accompanying map. Geophysical prospecting totaled 610 crew weeks for 1949 of which 372 crew weeks were seismic, 146 gravity, and 89 magnetic. Exploratory core drills were used a total of 76 crew weeks. Seven seismograph, one magnetometer and three gravity meter crews were operating in South Arkansas as the year ended.

A total of 84 wildcat wells were drilled in South Arkansas during 1949, of which four were the discovery

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wells of new fields and 80 were dry holes. The wildcat wells averaged 3,911 ft in depth or 267 ft less than the average depth of wildcats in 1948. Field wells drilled during the year in South Arkansas fields amounted to 258 and of this number 181 were producers and 77 were abandoned as dry. Of the producers 48 per cent were completed in Upper Cretaceous sands, 36 per cent in the Lower Cretaceous and only 16 per cent in Jurassic beds (mainly in the Smackover limestone).

Cumulative production from the oil and gas-condensate fields of South Arkansas to the end of 1949 totaled 784,918,470 bbl. Production of oil plus condensate in the region totaled 29,785,413 bbl in 1949, a decrease of 1,899,266 bbl from the 31,684,679 bbl produced in 1948. This drop is accounted for to some extent by the Arkansas Oil and Gas Commission's order effective June 6, which reduced the top allowables for wells in controlled fields by 15 per cent and the order issued effective June 16 after a public hearing which made such cuts in allowable as were necessary to reduce pipeline runs 15 per cent below the May runs.

Production of gas from the oil and gas-condensate fields of South Arkansas also decreased during 1949. In 1948 these fields produced 67,974,691 Mcf of gas while in 1949 production was 60,802,305 Mcf, a decrease of 7,172,386 Mcf.

Refinery runs to stills from the six refineries operating in South Arkansas were 17,726,253 bbl during 1949. Average daily runs to stills were 52,613 bbl in 1948 compared to 48,565 bbl in 1949.

The intake volumes of the ten gasoline plants in the region also decreased in 1949. The plant processed 59,752,686 Mcf of gas in 1949, a decrease of 1,290,053 Mcf from the 61,042,739 Mcf processed in 1948.

Magnolia Field, Columbia County, continued to lead all other fields in oil production with an annual output of 4,172,347 bbl for 1949. The large Smackover Field in Quachita and Union Counties was second with 3,900,867 bbl; Schuler Field in Union County was third largest producer with 3,136,438 bbl; and Wesson Field, Quachita County, fourth with production of 3,066,191 bbl for the year.

Anticipated and normal declines were observed in most of the stripper and a number of the older flush pools in South Arkansas. Of the stripper pools only Champagnolle, Stephens (Buckrange reservoir), Irma and Woodley, reflected an increase in production during 1949 over that for 1948. During the year stripper pools declined a total of 216,125 bbl net. Also, the Magnolia Field (Smackover limestone reservoir) declined 354,464 bbl, Schuler (Jones sand reservoir) 568,334 bbl and other controlled fields 2,557,908 bbl compared to their yields for 1948.

The results of pressure maintenance and other secondary recovery operations in South Arkansas fields for 1949 were very satisfactory and are briefly summarized below.

In the Midway Field, northern Lafayette County, one of the most successful pressure maintenance projects in the country has been in operation since 1943. The field lies along an east-west anticline and produces from the Smackover limestone (Jurassic) between 6,400 and 6,500 ft in depth over an area of about 1,800 acres. During 1949 the annual output totaled 2,684,363 bbl of oil (about 7,354 B/D) along with 857,986 bbl of water and 988 Mmcf of gas. Injection of fresh and salt water into the reservoir amounted to 3,993,170 bbl (10,940 B/D) for the year. The bottom hole pressure rose from 2,706 psi on Jan. 1, 1949, to 2,710 psi at the end of the year, an increase of four psi. Of the 45 wells that produce from the Smackover limestone, 30 are still flowing. Ultimate recovery with water injection is estimated at 65 to 80 million bbl, whereas without water injection it is estimated at 28 million bbl.

In the Schuler Field located on an anticline in western Union County, gas has been injected into the Jones sand at the base of the Cotton Valley formation (Jurassic) about 7,550 ft in depth, since July 1941. Water injection into the Jones sand reservoir was begun in June, 1944. For the year 1949 production from the Jones sand amounted to 2,678,029 bbl of oil (averaging 7,337 B/D) with 11,884,536 cu ft of gas and 561,155 bbl of water. During the year 10,331,112 cu ft of gas (about 28,304 cu ft per day) and 1,688,501 bbl of fresh and salt water (averaging 28,304 B/D) were injected into the Jones sand. The pressure dropped 38 psi during the year due largely to lack of sufficient extraneous gas which was formerly available for injection purposes.

The Haynesville Field, three-quarters of which lies in Louisiana and one-quarter in Arkansas, has had a gas-injection project in operation in the center of the field in Louisiana since 1945, the gas being put into the gas cap of the Pettit limestone reservoir, Sligo formation (Lower Cretaceous). The injection of gas, however, has little or no effect on the Arkansas segment of the field where 34 wells yield oil and gas from the Pettit limestone at depths around 5,400 ft. Water flooding in this reservoir was begun in 1947 and 29 input wells are now used, seven of which are in Arkansas. The Arkansas segment of the field produced 362,698 bbl of oil (990 B/D) with 236,313,000 cu ft of gas and 30,314 bbl of water during 1949. Water injection into the reservoir during the year totaled 5,433,073 bbl, or an average of 14,880 B/D. During 1948 the bottom hole pressure in the Arkansas segment declined 331 psi but in 1949 the decline amounted to only 51 psi, proof that the drop in bottom hole pressure is being arrested by water injection. Approximately 3,500,000 bbl of oil will be produced in the Arkansas segment of the Haynesville Field over and above the estimated output without water flooding.

The Magnolia Field situated on an east-west anticline in Columbia County produces mainly from the Reynolds oolite of the Smackover limestone (Jurassic) around 7,500 ft in depth. Operation of a salt water disposal and pressure maintenance project for this zone was begun in 1946. During 1949 a total of 4,172,347 bbl of oil (11,431 B/D) were produced from this reservoir along with 4,550,820,000 cu ft of gas and 2,894,590 bbl of water. During the year 5,100,749 bbl of fresh and salt water (13,950 B/D) were injected into the water table through four input wells. The reservoir pressure declined from 2,779 psi to 2,743 psi or a drop of 36 psi for the year which is approximately the same pressure decline as in 1948. A relatively strong water drive existed in the Smackover limestone prior to water injection and the amount of increased production due to water injection is difficult to calculate. The principal benefit of the project lies in permitting oil to be produced at a faster rate than would be possible with highly restricted withdrawal rates than would have been imposed if water injection had not been undertaken.

The Hogg sand pool of the Wesson Field, Quachita County, is located on the high (southwest) side of two closely spaced step faults downthrown to the northeast. The reservoir is a relatively narrow sand bar terminated upstructure by the step faults and downstructure by a water level. It lies at the base of the Pine Island formation at an average depth of 3,150 ft. Water injection into the Hogg sand began late in 1948. During 1949 a total of 67 unit oil wells were used to produce 1,923,371 bbl of oil (5,269 B/D) together with 227,787,000 cu ft of gas and 153,354 bbl of water. In the same period 2,759,516 bbl of water (7,560 B/D) were injected into the reservoir through six input wells. The bottom hole pressure was raised from 369 psi at the beginning of 1949 to 469 psi at the end of the year or an increase of 100 psi. Estimated recovery from the pool with water injection is 30,185,000 bbl of oil or more than two and one-half times the estimated recovery by ordinary production methods.

The Hogg sand pool of the Stephens Field, Quachita County, which lies about 3,240 ft in depth, was discovered in May, 1949. It is described under "New Reservoirs" in this review. The pool was drilled on a 20-acre spacing pattern and contained 14 producing wells at the end of the year. This development showed the producing limits to contain approximately 353 acres and average producing thickness to be 15 ½ ft. Production to the end of the year totaled 199,288 bbl of oil, 3,950,000 cu ft of gas and 101,172 bbl of water. The pool derives its energy solely from solution gas. The original reservoir pressure was 1,323 psi and the pressure at the end of the year 416 psi, or a decline of 907 psi. Only 220 bbl of oil were produced per pound drop in pressure. This rapid decline accompanied by small oil production caused the operators to unitize their holdings for the purpose of injecting water to augment reservoir pressure and increase oil recovery. Unitization was almost completed as the year ended.

In the McKamie-Patton Field located on an east-west anticline in Lafayette County producing mainly gas and condensate from the Reynolds oolite of the Smackover limestone (Jurassic), gas-recycling operations were begun in August 1949. A total of 2,214,756,000 cu ft of gas was injected into the reservoir through two input wells from August to December, inclusive. The project is too new and data too few to evaluate results of gas-recycling at the end of the year. Estimated recovery with gas injection is 40,763,000 bbl of condensate (or 73 per cent of the condensate in place in the reservoir) and 9,852,000 bbl of oil (36 per cent of the oil in place).

The Atlanta Field which lies on an east-west anticline in eastern Columbia County and produces chiefly from the Reynolds oolite of the Smackover formation at about 8,200 ft in depth, has had a salt water disposal project in operation since 1946. Only one input well on the edge of the reservoir has been used. Through it 3,194,447 bbl of fresh and salt water were injected to date, of which 1,233,723 bbl were put into the reservoir in 1949. There is no doubt but that injection of water is retarding the drop in reservoir pressure but because only one salt water disposal well has been employed and sufficient bottom hole pressure data are lacking the results cannot be determined adequately.

Only brief mention has been made of new discoveries. Several of the wildcat wells drilled during the year opened new fields and of the 185 producers completed in the fields of South Arkansas many encountered new reservoirs or enlarged the known producing limits of old reservoirs. The new fields, extensions in depth (new reservoirs) and in area are described below.

NEW FIELDS

LOUTRE CREEK FIELD

The Loutre Creek Field, discovered April 9, 1949, on an anticline in southern Union County, produces oil from the Reynolds oolite of the Smackover limestone (Jurassic). It is a one-well field ringed with five offset dry holes drilled to the Smackover limestone during the year. The new discovery is, therefore, of small importance and contributes little to the oil reserves of the state.

The discovery well, MacMillan Petroleum Co. and Zach Brooks Drilling Co. #1 Cleg Nash et al., located in the center of SE ¼ NW ¼ Sec. 35, T. 18 S., R. 15 W., topped the porous productive Reynolds oolite at 7,767 ft. The water level in this zone is believed to have been penetrated at 7,784 ft and the hole was bottomed in Smackover limestone at 8,010 ft. The casing (5 ½-in.) set at 7,874 ft, was penetrated with 12 shots from 7,769 to 7,772 ft. Oil of 40.6° gravity flowed through these openings at an initial rate of 144 B/D on a 10/64-in. choke; tubing pressure was 1,075 psi; bottom hole pressure 3,300 psi; and the gas-oil ratio 559:1.

The five dry and abandoned offsets encircling the discovery well were drilled by Marine Oil Co. and Zach Brooks Drilling Co. to various depths between 7,758 and 7,963 ft.

PINE TREE FIELD

The Pine Tree Field, discovered Jan. 20, 1949, by Lion Oil Co., lies from one-half to one mile south of the Atlanta Field in Columbia County, on a small dome and yields oil from the porous Reynolds oolite zone of the Smackover limestone (Jurassic). The new field is sometimes referred to as a satelite of the Atlanta Field.

Lion Oil Co. #1 Story, the discovery well, was drilled in the center of NE ¼ SE ¼ Sec. 20, T. 18 S., R. 19 W., to a total depth of 8,476 ft. Casing (5 ½-in.) set at 8,474 ft was perforated with 48 shots opposite the upper part of the Reynolds oolite between 8,426 and 8,433 ft. Oil of 44.2° gravity flowed from this zone at an initial rate of 650 bbl in 21 hours on a 1/4-in. choke; tubing pressure was 900 psi; shut-in pressure 1,350 psi and gas-oil ratio 1,100:1.

Two additional producers were drilled in the Pine Tree Field during the year on a 40 acre spacing pattern, namely: Lion Oil Co. #1 Magnolia, located 200 ft east of the center of the NW ¼ SE ¼ Sec. 20, T. 18 S., R. 19 W., completed during April, and Lion Oil Co. #1 Cross, 199 ft south of the center SE ¼ NE ¼ Sec. 20-18-19, completed in June. The former flowing from the Reynolds oolite through perforations at 8,392-8,400 ft, yielded initially 257 B/D on a 16/64-in. choke; tubing pressure 550 psi; gas-oil ratio 1,000:1. The latter well producing from the same zone through perforations at 8,414-30 ft, flowed initially at the rate of 132 B/D on an 8/64-in. choke; tubing pressure 1,685 psi; gas-oil ratio 1,500:1.

The three producers completed during 1949 may effectively drain the small Smackover limestone reservoir in the Pine Tree Field.

SPOTTSVILLE FIELD

A new field was discovered in Columbia County about three miles southeast of the Village Field and two miles northeast of the Atlanta Field, by the McAlester Fuel Co. and Curtis Kinard #A-1 T. O. Giles Estate well drilled in the center of NW ¼ NE ¼ Sec. 6, T. 18 S., R. 18 W. The casing (5 ½-in.) set at 7,876 ft, bottom of the hole, was perforated at 7,766-71 ft opposite the porous Reynolds oolite of the Smackover limestone (Jurassic). On June 23, 1949, the initial production was gauged at 95 bbl of oil (45° gravity) and 1,263,000 cu ft of gas through a 11/64 in. choke; tubing pressure 1,700 psi; bottom hole pressure 3,165 psi; and gas-oil ratio 13,293:1. Following a test period of 90 days the well was shut-in for the remainder of the year pending utilization of the gas.

WARNOCK SPRINGS EXTENSION

Either a northeastward extension to the Warnock Springs Field in Columbia County, or a new field on the same anticlinal ridge, was discovered Dec. 8, 1949, with the completion of McAlester Fuel Co. #A-1 Phillips-Shocklee as a producer from the Reynolds oolite of the Smackover formation. The well was drilled to 7,403 ft in the center of NE ¼ SW ¼ Sec. 33, T. 16 S., R. 19 W., and 5 ½-in. casing which was set at 7,403 ft, was perforated opposite the top of the porous oolitic zone at 7,394-7,403 ft. Approximately 750,000 cu ft of gas and 25 bbl of condensate (68° gravity) flowed through these openings and a 10/64-in. choke during the initial production test. Tubing pressure was 2,250 psi and gas-oil ratio 30,000:1. The well was shut-in during the remainder of the year pending the construction of a pipeline connection.

NEW RESERVOIRS

ATLANTA FIELD

The Atlanta Field which is situated along an east-west anticline in Columbia County, producing mainly from the porous oolitic zone of the Smackover formation (Jurassic) in 46 wells, also yields oil and gas from small sand lenses of the Cotton Valley formation (Jurassic) in 14 wells. Four new Cotton Valley sand lenses were found to be productive in 1949. They are, however, unimportant and add but little to the reserves of the state.

Two of the new Cotton Valley oil sands were encountered in Bradham and Ragsdale #1 Longino Goode drilled to 8,233 ft in the center of the SE ¼ SE ¼ Sec. 8, T. 18 S., R. 19 W., which yielded small oil production from the Smackover limestone before being dually completed June 22, 1949, in new sands. The upper sand lens was opened through perforations at 6,982-88 ft, flowing 40° gravity oil at an initial rate of 130 B/D on a 12/64-in. choke. The other new Cotton Valley lens produced 42° gravity oil through perforations at 7,390-94 ft and after flowing for a short period "died". The upper sand was then produced by pumping and at the end of the year was yielding only 10 B/D.

A small Cotton Valley sand lens was discovered to be productive March 25, 1949, in a recompletion of the Wheless Drilling Co. #1 D. D. Goode, 100 ft south of the center of SE ¼ NW ¼ Sec. 16, T. 18 S., R. 19 W., which produced for eight years from the oolitic zone of the Smackover limestone. The new sand lens, opened through perforations at 7,485-90 ft, yielded 48° gravity oil which was pumped at an initial rate of 57 B/D.

Another new productive Cotton Valley sand lens was discovered in the Deep Rock Oil Co. #1 Bonnie Davis drilled 8,285 ft deep in the center of the NW ¼ NE ¼ Sec. 17, T. 18 S., R. 19 W. This well produced a small quantity of oil from the Reynolds oolite during September before being plugged back and completed Oct. 6, 1949, in the new Cotton Valley lens through perforations at 7,947-53 ft, flowing from the new sand at an initial rate of 72 bbl of 48° gravity oil daily on an 8/64-in. choke; the gas-oil ratio was approximately 5,000:1.

In addition to the four completions in new oil sands enumerated above, one completion and seven recompletions (an unusually large number) were made during the year in a previously known productive zone of small sand lenses between 7,100 and 7,340 ft where correlation between individual lenses is generally not possible.

BUCKNER FIELD

The Buckner Field located along an east-west anticline in Columbia and Lafayette Counties, producing from the Smackover limestone (Jurassic) around 7,200 ft, and also from several sand lenses in the Hosston formation (Lower Cretaceous), was extended slightly during the year in both depth and area. Prior to 1949 three Hosston sand lenses yielded oil around 4,640; 4,710; and 4,800 ft, respectively. During the year another Hosston sand lens was found to be productive at about 4,990 ft when, on June 25, Carter Oil Co. completed their #1 Fee situated 560 ft south and 660 ft east of the NW corner NW ¼ NW ¼ Sec. 17, T. 16 S., R. 22 W. Oil of 36.7° gravity flowed from the new reservoir through perforations between 4,985 and 4,990 ft at an initial rate of 144 B/D on an 8/64-in. choke; tubing pressure 450 psi. An east offset to this well, Carter Oil Co. #1 J. B. Wilson Est. was completed during July, 1949 in the same sand as a producer.

The proved area at Buckner was enlarged about 1/4 mile southward along the east end of the field by two wells completed in the main producing sand of the Hosston formation below 4,800 ft in depth, namely: the J. W. Watts et al, #1 and #2 L. L. Nix in SE¼ NE¼ and SW¼ NE¼ respectively, in Sec. 16, T. 16 S., R. 22 W. At the end of the year the field consisted of 27 wells producing from Hosston sand lenses and 24 producers from the Smackover limestone.

DORCHEAT-MACEDONIA FIELD

In the Dorcheat-Macedonia Field of western Columbia County (producing since 1939) a record number of recompletions were effected during 1949. The field lies on an east-west anticline and yields oil, condensate and gas from the porous oolitic Smackover limestone (Jurassic) and from many sand lenses of the Cotton Valley formation (Jurassic). During the year only two wells were recompleted in the Smackover limestone reservoir at depths of 8,826-46 ft and 8,890-98 ft, respectively. However, 12 recompletions were made in the lenticular sands of the Cotton Valley formation. Some of these lenses appear to be so small as to be productive only in one well and although they may be new reservoirs they are of little importance.

At the end of 1949 the field contained 37 wells yielding oil from Cotton Valley sand lenses, 45 wells producing gas and condensate from Cotton Valley sand lenses and 46 wells were producing gas and condensate from the Smackover limestone. Some of the wells yielded oil and gas from different zones by means of dual completions.

GUM CREEK FIELD

The Gum Creek Field in southern Quachita County, producing from several upper Cretaceous sands along the high (south) side of a fault, was enlarged slightly during the year in both depth and area. A new reservoir, a tight sand stringer, known as the third Blossom sand, was brought into production May 7, 1949, when Carter Oil Co. recompleted the #1 Crowley well in SW ¼ NE ¼ NE ¼ Sec. 27, T. 15 S., R. 18 W. The new sand stringer was opened through perforations at 2,359-64 ft., and the casing was also perforated opposite the thin second Blossom oil sand at 2,321-30 ft. Initially the well pumped 128 B/D from both sand stringers.

The productive area of the Gum Creek Field was extended about one-third mile northeastward with the completion of Carnes and Milam #1 Dave Brown in SE ¼ SE ¼ SW ¼ 23-15-18, Jan. 12, 1949. Bottomed at 3,506 ft the hole was plugged back to 2,350 ft and the casing perforated at 2,294-2,300 ft opposite the first Blossom sand which yields gas. The initial output was 5 Mmcf of gas per day on open flow. At the end of the year the Gum Creek Field was producing from two gas wells and 17 wells yielding oil on artificial lift.

HILLSBORO FIELD

The Hillsboro Field situated on a gentle anticline in Union County, producing from 1930 to late in 1949 from only the Nacatoch sand (Upper Cretaceous), was extended slightly both in depth and area by one of the seven wells drilled in the area during the year. The well, Dorset Co. and R. H. Crow, Tr. #101 Union Saw Mill, located in the center of NE ¼ SW ¼ NE ¼ Sec. 11, T. 18 S., R. 14 W., was bottomed at 4,010 ft, and the casing, set at 4,007 ft, was perforated at 3,937-45 ft opposite a lenticular sand of the Hosston formation (Lower Cretaceous), a new reservoir for the field. Oil of 34° gravity flowed from this zone at an initial rate of 240 bbl in 17 ½ hours with 50 bbl of salt water. The well then went "dead". A pumping test yielded ten bbl of oil and 350 bbl of salt water per day but when finally completed on Dec. 9, 1949, the well pumped initially seven bbl of oil and 300 bbl of salt water per day. The new producer also extended the limits of the field about one-quarter mile northward. Of the six other wells drilled in the area during the year, three were dry holes and three were completed in the Nacatoch sand pumping two to 12 B/D. At the end of the year the field was producing from 33 pumping wells and an attempt was being made to unitize the Nacatoch sand pool for the purpose of injecting water in order to increase the recovery of oil.

LEWISVILLE-WEST FIELD

The Lewisville-West Field which has yielded a negligible output of oil since 1946 along a fault in Lafayette County, contains two producing wells. One of these, McAlester Fuel Co. #1 L. Hook in the NE ¼ NE ¼ Sec. 17, T. 16 S., R. 24 W., was recompleted April 24, 1949, in a new reservoir for the field. The well produced originally (1947) through perforations at 3,818-33 ft. These openings were squeezed and the new reservoir, a deeper sand lens in the Paluxy formation (Lower Cretaceous) adjacent to the fault, was opened through perforations at 3,927-31 ft. The well pumped oil from this sand at an initial rate of 128 B/D.

MAGNOLIA FIELD

In the large Magnolia Field, Columbia County, a new thin lenticular sand of the Cotton Valley formation (Jurassic) was discovered to be productive in 1949. The field produces mainly from porous oolitic Smackover limestone (Jurassic) around 7,500 ft in depth, on an east-west anticline, and, to a much less extent from several zones of lenticular sands in the Cotton Valley formation. During the year three producers were drilled and completed in the Smackover limestone reservoir, two other wells drilled became producers from old Cotton Valley oil sands, and three old wells were recompleted in Cotton Valley sands. In one of the recompletions, Atlantic Refining Co. #D-2 Garrett, the new producing level in the Cotton Valley was encountered. This well located in the center of NE ¼ NW ¼ Sec. 24, T. 17 S., R. 20 W., was perforated opposite the new lens at 5,540-46 ft. Oil from this zone, however, was produced with that from two other known reservoirs in the well, one above and the other below the new level. The well flowed 156 B/D on a 10/64-in. choke from the three sand stringers when completed on July 22. The Magnolia Field consisted of 108 wells producing from the Smackover limestone and ten Cotton Valley producers at the end of the year.

SPIRIT LAKE FIELD

A new producing zone was found in the Spirit Lake Field, Lafayette County, which, at the beginning of 1949, yielded oil and gas from five Lower Cretaceous zones (two reservoirs in the Paluxy, one in the Mooringsport and two in the Rodessa formation). The new producing zone also in the Lower Cretaceous was discovered in Joe Mucher, Tr., #K-1 Moore Est., in SW ¼ NE ¼ Sec. 14, T. 16 S., R. 25 W. The well was first completed through perforations at 3,968-93 ft, in what is believed to be the fault zone in the Mooringsport formation where relatively small production was obtained over a period of several months. During July the well was recompleted through perforations at 3,600-06 ft opposite the new reservoir flowing initially 72 B/D on a 1/2-in. choke; tubing pressure 100 psi. Unusual features of this completion are: (1) that the oil comes from the Goodland limestone (Lower Cretaceous) which produces nowhere else in Arkansas and (2) that this reservoir is on the downthrow (north) side of the fault whereas all other producing zones in the field are on the upthrow (south) side. At the end of 1949 the Spirit Lake Field consisted of three flowing and 15 pumping wells, producing from the various reservoirs in the Lower Cretaceous and one additional well was shut-in.

STEPHENS FIELD

Extensions were made to the Stephens Field during 1949, both in depth (by the opening of new reservoirs) and in area which resulted in the discovery of more new oil production and additional proved reserves than were developed during the year in any other field of the state.

The large Stephens Field is located where Nevada, Quachita and Columbia Counties corner and has produced since 1922, almost entirely along the high (south) side of a major fault marking the south edge of a graben, the production coming from multiple zones, namely: the Nacatoch, Buckrange and Lower Tokio sands of Upper Cretaceous age and from numerous sand lenses in the Glen Rose and Hosston beds of Lower Cretaceous age.

The extensions to the field during 1949 may be referred to two general areas: (1) the high (south) side of the aforementioned fault in the Stephens Field proper and (2) north of this fault within the graben. On the high (south) side of the fault discovery of production from the Hogg sand at the base of the Pine Island formation (Lower Cretaceous) was of major importance and opening of the Upper Tokio sand to production of minor interest. In the graben area discovery of the Stephens-Curry extension at the northeast side of the field with production coming from several zones in the Hosston formation was a major development and an extension by two wells in the graben on the north side of the field (approximately a mile west-northwest of the Stephens-Curry area) of minor importance. These discoveries will be described in the order mentioned.

(1) HOGG SAND POOL

The Hogg sand pool is situated on a small nose extending southeastward from the major "high" of the field in the Stephens-Smart area immediately south of the graben. The Hogg sand is at the base of the Pine Island formation (Lower Cretaceous) around 3,250 ft in depth. It was discovered to be productive in the Stephens Field with the completion on April 16, 1949, of Z. Brooks and C. G. Davis #1 J. Hamilton in the center of NW ¼ SW ¼ NE ¼ Sec. 19, T. 15 S., R. 19 W. The new reservoir was opened through perforations at 3,242-53 ft. Oil of 34° gravity flowed through these openings at an initial rate of 456 B/D on a 1/4-in. choke; tubing pressure was 154 psi, bottom hole pressure 1,308 psi, and gas-oil ratio 10:1.

Development of the Hogg sand pool proceeded on a 20-acre spacing pattern and 13 additional wells were drilled and completed in it before the end of the year. Six of these flowed at initial rates between 159 and 237 B/D on various sized chokes and the remaining seven wells pumped initially from 54 up to 308 B/D. Rapid decline in reservoir pressure accompanied by relatively small production was noted shortly after the pool was discovered and operators recognized early that unless water was injected to repressure the Hogg sand, a considerable part of the oil in place would remain irretrievably in the reservoir. By the end of the year the most of the interests in the Hogg sand pool had been unitized and preliminary studies for repressuring the reservoir were completed. The Arkansas Oil and Gas Commission cooperated in the project. The producing limits of the Hogg sand were fairly well established as the year ended and the pool showed the following characteristics:

The productive area covered 354 acres and contained 14 producers. The net oil sand varied in the wells from six to 44 ft with a weighted net average thickness of 15.43 ft. Subsea depth of the reservoir is approximately 2,975 ft and the water table in it was at 3,016 ft subsea. From an initial bottom hole pressure of 1,308 psi the pressure had dropped to 416 psi (a decline of 892 psi) at the end of the year while 201,600 bbl of oil were being produced or approximately 225 bbl of oil per pound drop in pressure. Of the 14 wells six were making water. The data indicate an undersaturated reservoir deriving its energy almost solely from solution gas. With present methods of operation, ultimate recovery would not exceed 300 bbl of oil per acre-ft or 1,637,000 bbl, whereas under unitized water-flood operations the ultimate recovery is estimated at 560 bbl per acre-ft or 3,056,000 bbl, reflecting an increase in ultimate recovery of about 1,419,000 bbl of oil.

At the end of 1949 the operators were negotiating with a company to install and operate a water-flood project for the Hogg sand pool at Stephens and the injection of

water into the reservoir was expected to start during May, 1950.

(1-A) UPPER TOKIO SAND

Although the Upper Tokio sand (Upper Cretaceous) had tested oil in many wells in the Stephens-Smart area of the field, no commercial production is known to have been obtained from this zone prior to 1949. The oil in the Upper Tokio sand is heavy and wells were completed in one of the deeper zones yielding lighter oil, the Lower Tokio sand being one of the most prolific of these.

Maritzky and Bibby #4 J. F. Smart drilled in the center of SW ¼ NE ¼ Sec. 13, T. 15 S., R. 20 W., was completed during December, 1949 as a producer from the Upper Tokio sand. The well was bottomed at 2,352 ft and casing was set on top of the sand at 2,350 ft. The well pumped 17° gravity oil together with salt water from the two feet of open hole in the top of the new reservoir at an initial rate of 30 bbl of oil plus approximately 100 bbl of water per day.

(2) STEPHENS-CURRY EXTENSION

The Stephens-Curry extension, considered a faulted segment of the Stephens Field, enlarged the productive area about a mile northeastward and also extended the field in depth with the discovery of new reservoirs in the Hosston formation (Lower Cretaceous).

The Stephens-Curry area was opened to production on July 4, 1949 by the Burnett Drilling Co. #1 Curry located 150 ft east 330 ft north of the southwest corner Sec. 5, T. 15 S., R. 19 W. The well was bottomed at 4,486 ft and the casing perforated at 3,608-20 ft opposite the new reservoir, a Hosston sand. Oil of 33° gravity flowed from this zone at an initial rate of 432 B/D; tubing pressure was 65 psi; casing pressure 125 psi; and gas-oil ratio 150:1. The discovery well penetrated a fault zone of around 1,100 ft displacement and cut the major fault in the Hosston formation just above the producing sand. The fault trends in an east-west direction and is downthrown to the south. All the wells completed in the Curry segment of the field during the year produce on the high (north) side of the fault. The discovery well was recompleted during December in a deeper Hosston sand through perforations at 3,730-35 ft, and pumped initially 105 B/D with two per cent salt water from the new reservoir.

Seven wells in all were completed as producers in the Stephens-Curry segment of the field during 1949. Following are brief descriptions of the other six wells: Burnett Production Co. #A-4 Kate Curry in NW ¼ SW ¼ SW ¼ Sec. 5, T. 15 S., R. 19 W., first perforated in a sand in the base of the Glen Rose beds (Lower Cretaceous) at 2,967-76 ft, pumped for a short period from this reservoir before being recompleted in a Hosston sand at 3,316-27 ft, where the initial output by pumping was 130 B/D. The Burnett Production Co. #B-2 Kate Curry in the center of NW ¼ SE ¼ SW ¼ Sec. 5, T. 15 S., R. 19 W., produced from a Hosston sand through perforations at 3,320-27 ft, pumping 32° gravity oil at an initial rate of 116 B/D. Burnett Production Co. #B-3 Kate Curry in the center of NE ¼ SE ¼ SW ¼ Sec. 5, T. 15 S., R. 19 W., opened a Hosston sand to production through perforations at 3,173-78 ft, pumping 33° gravity oil at the rate of 108 B/D initially. Burnett Production Co. #A-2 Lester Realty Corp. in the center of NE ¼ SE ¼ SE ¼ Sec. 6, T. 15 S., R. 19 W., was completed in the Hosston through perforations at 3,313-23 and 3,327-30 ft, pumping initially 105 B/D. Lee and Burnett #A-2 Kate Curry in the center of NE ¼ SW ¼ SW ¼ Sec. 5, T. 15 S., R. 19 W., flowed initially from a Hosston sand between 3,314 and 3,324 ft, approximately 300 bbl of 30° gravity oil daily; tubing pressure was 65 psi and casing pressure 90 psi. Lee and Burnett #A-3 Kate Curry located 50 ft west of the center of NE ¼ SW ¼ SW ¼ Sec. 5, T. 15 S., R. 19 W., perforated in the Hosston at 3,232-44, 3,246-49 and 3,252-56 ft., pumped initially 104 B/D. One well, Lee and Burnett #A-1 J. E. Morgan, although temporarily abandoned in 1949 had shows of oil in the Glen Rose beds on the downthrow side of the fault. The operator will retest this zone in 1950 and expects eventually to deepen the well to cut the fault and test the upthrow (north) side in the Hosston formation.

(2-B) NORTH EXTENSION STEPHENS FIELD

Two isolated wells located in the graben about a mile west-northwest of the Stephens-Curry extension and one-third to three-quarters of a mile, respectively, north of the main Stephens Field, enlarged the producing area northward towards the small North Stephens Field and also extended the field in depth by the discovery of new producing zones.

The H. T. Pannell #1 Bannister drilled during August in the center of SE ¼ SE ¼ NE ¼ Sec. 1, T. 15 S., R. 20 W., cut a small fault (50 ft displacement) in the Upper Cretaceous around 2,236 ft and penetrated a new reservoir, a sand in the Rodessa section of the Glen Rose beds (Lower Cretaceous). The casing was perforated opposite this zone at 2,932-38 ft, and oil of 28° gravity was pumped at an initial rate of 240 B/D.

The other isolated producer in the northward extension of the field within the graben, Maritzky and Bibby #1 Clyde Bannister, was drilled in the center of NE ¼ SW ¼ SE ¼ Sec. 1, T. 15 S., R. 20 W. The well after cutting a fault of about 80 ft displacement immediately below the James limestone encountered a productive sand at the top of the Pine Island formation in the Glen Rose series. The casing was perforated at 3,591-97 ft opposite this zone and from it oil of 28° gravity was pumped at an initial rate of 68 B/D.

VILLAGE FIELD

The Village Field, Columbia County, produces along an anticline from multiple sand lenses in the Hosston (Lower Cretaceous) and Cotton Valley (Jurassic) formations as well as from the Smackover limestone (Jurassic). Two new producing sand lenses were discovered in the field in 1949, one in the Sligo formation at the base of the Glen Rose series of beds (Lower Cretaceous) and the other in the Cotton Valley formation.

The upper new sand lens was found in the C. W. Williams, R. T. Sellars and Wilson Ewing #1 J. G. Alexander, located 460 ft west and 660 ft north of the SE corner SW ¼ SE ¼ Sec. 8, T. 17 S., R. 19 W. The casing was perforated opposite the new sand (only producing zone in the Glen Rose in the field) at 3,990-4,002 ft. Oil of 32° gravity flowed through these perforations at an initial rate (July 17, 1949) of 132 B/D on a 1/4-in. choke; tubing pressure 90 psi and gas-oil ratio 181:1.

The lower of the two new reservoirs was found June 2, 1949 in a recompletion of McAlester Fuel Co. #A-1 E. D. Harris located in the center of SW ¼ SW ¼ Sec. 10, T. 17 S., R. 19 W. The well formerly produced from 5,532-44 ft in the Cotton Valley formation. These openings were plugged and the casing reperforated at 5,508-14 ft (the new sand) and 5,532-40 (the old sand). Oil of 43° gravity flowed from the two sand lenses at an initial rate of 179 B/D on a 12/64-in. choke; the gas-oil ratio was estimated at 700:1. No other producer was completed in either of the two reservoirs discovered in 1949.

As the year ended the Village Field was producing in 43 wells from the Smackover limestone and in 50 wells from sand lenses in the Hosston and Cotton Valley formations.

WESSON FIELD

Two new productive sands, the first Blossom sand (Upper Cretaceous) and a lens in the Travis Peak (Lower

Cretaceous) were discovered during the year in the Wesson Field, Quachita County. The field lies mainly on the high (southwest) side of two closely spaced step faults downthrown to the northeast and has produced for several years from multiple zones, namely: the Nacatoch, Buckrange and Tokio sands (Upper Cretaceous) and from numerous lenticular sands in the Glen Rose and Hosston (Lower Cretaceous).

The first Blossom sand was opened to production Oct. 10, 1949 in the G. E. Carson et al., #1 Wesson Heirs located 100 ft west of the center of NE ¼ NE ¼ NW ¼ Sec. 23, T. 15 S., R. 19 W. It was penetrated at 2,203-11 ft, or about 40 ft below the Buckrange sand: The casing was perforated from 2,150 to 2,212 ft to include production from the thin Buckrange sand as well as from the first Blossom sand and the well pumped initially 40 bbl of 29.6° gravity oil per day. The first Blossom sand was producing in six additional wells by the end of the year. These wells also were completed in both the Buckrange and first Blossom sands and pumped initially between 25 and 40 B/D. This development extended the productive area on the north side of the Wesson Field westward about one-third mile connecting it with the old East Stephens Field which has produced for many years from the Nacatoch and Buckrange sands.

A new productive Hosston sand lens was discovered April 12, 1949 in the recompletion of McAlester Fuel Co. #B-2 R. W. Wesson located in the center of NE ¼ SE ¼ SE ¼ Sec. 24, T. 15 S., R. 19 W., drilled during 1946. The former perforations at 3,268-90 ft were plugged and the casing reperforated at 3,222-32 ft opposite the new reservoir from which oil flowed at an initial rate of 76 B/D through a 14/64-in. choke; tubing pressure 1,200 psi.

The Wesson Field consisted of 33 wells producing from Upper Cretaceous sands, 105 wells producing from Glen Rose sand lenses (70 of which were Hogg sand wells) and 13 Hosston producers as the year ended.

EXTENSIONS TO OLD RESERVOIRS

BEAR CREEK FIELD

The small Bear Creek Field, located on an anticline in the northwest corner of Union County was enlarged about one-quarter mile in several directions, namely, towards the northwest, south and east by four wells completed during the year in the porous Reynolds oolite of the Smackover formation (Jurassic) sole producing reservoir of the field. All four wells were drilled by Grady H. Vaughn and were perforated at various levels between 6,348 and 6,392 ft. The four wells are: #A-3 Annie Smith in NW ¼ NE ¼ Sec. 17, T. 16 S., R. 17 W.; #E-2 Annie Smith in SW ¼ SW ¼ Sec. 9, T. 16 S., R. 17 W.; #F-2 Annie Smith in NE ¼ NW ¼ Sec. 17, T. 16 S., R. 17 W.; and #1 Watson Heirs in NE ¼ SW ¼ Sec. 8, T. 16 S., R. 17 W. All except #E-2 Annie Smith flowed initially at rates between 110 and 136 B/D (gravity 28-29°) plus varying amounts of water. The #E-2 Annie Smith pumped 122 bbl of oil and 22 bbl of salt water initially. The field contained nine producers at the end of the year.

CAIRO FIELD

The Cairo Field in western Union County, discovered in 1948, yielding oil and gas from the Reynolds oolite of the Smackover limestone (Jurassic) was enlarged on all sides except the north and northeast by wells drilled during 1949. The field, sometimes called a satelite of the Schuler Field which is less than two miles to the southwest, lies on a domal anticline extending southwest-northeast or at right angles to the usual trend for Smackover limestone fields. Nine producers were completed in the Cairo Field during the year at varying levels between 7,740 and 7,883 ft, flowing initially between 84 and 335 B/D (gravity 36-39°) from the Reynolds oolite of the Smackover formation on various size chokes; average tubing pressure was around 1,100 psi and average gas-oil ratio about 800:1. Eight of the nine producing wells enlarged the proved productive area. They are: Phillips Petroleum Co. #1 Owner in NE ¼ SE ¼ Sec. 4, T. 18 S., R. 17 W., and Carter Oil Co. #1 Edwards Est. in SW ¼ SE ¼ Sec. 4, T. 18 S., R. 17 W., both of which extended the field about one-quarter mile toward the northwest; Carter Oil Co. #1 Ida Edwards in NW ¼ NE ¼ Sec. 9, T. 18 S., R. 17 W., and Atlantic Refining Co. #1 B. F. Justiss in NE ¼ NW ¼ Sec. 9, T. 18 S., R. 17 W., which together enlarged the productive area one-third mile to the west; the Carter Oil Co.'s #1 Mattie Emerson in NW ¼ SE ¼ Sec. 9, T. 18 S., R. 17 W., and #1 R. B. Wilson in NE ¼ SE ¼ Sec. 9, T. 18 S., R. 17 W., both of which extended the producing limits about one-quarter mile farther southwest; Phillips Petroleum Co. #1 Primm 717 ft north and 1,899 ft east of the SW corner Sec. 3, T. 18 S., R. 17 W., together with Carter Oil Co. #1 H. P. Sewell in SW ¼ NW ¼ Sec. 10, T. 18 S., R. 17 W. extended the field about one-fourth mile eastward. At the end of the year the field consisted of 16 producing wells.

HIBANK FIELD

The small Hibank Field in southern Union County was doubled in area by wells drilled during 1949. The field lies on a fairly extensive "high" on the upthrow (south) side of a fault and produces from numerous small thin sand lentils scattered throughout the thick sandy shale series comprising the Nacatoch formation (Upper Cretaceous) in this area. The productive spots are due to the occurrence of porosity and permeability in the sand lentils. Seven wells were drilled in the field during 1949 and were completed as producers at varying depths between 2,056 and 2,210 ft in the Nacatoch formation. The wells pumped initially between two and 14 B/D. Four of these drilled by Kilmarnock Oil Co. in Sec. 30, T. 18 S., R. 14 W., extended the productive area three-fourths mile southward on the east side of the field. The R. M. Crabtree #2 J. C. Woods et al., in NE ¼ NE ¼ NW ¼ Sec. 36, T. 18 S., R. 15 W. enlarged the productive area southward about one-fourth mile on the west side of the field. At the end of the year the field contained nine pumping wells and a gas well.

LEWISVILLE FIELD

In the Lewisville Field, Lafayette County, producing since 1939 mainly from the Kilpatrick limestone, Rodessa formation (Lower Cretaceous) with a small additional output from the Tokio sand (Upper Cretaceous) on the high (south) side of a fault, two producers were completed near the end of the year in the Tokio sand and extended the productive area of the field in the east-central portion about one-fourth mile southward. The two new Tokio producers, both drilled by J. B. Warmack et al., were the #2 Judy Bell in NW ¼ SW ¼ NW ¼ Sec. 19, T. 16 S., R. 23 W. and #1 Bell Estate in NE ¼ SW ¼ NW ¼ Sec. 19, T. 16 S., R. 23 W. In the former, the Tokio sand produced through perforations at 2,292-2,300 ft flowing initially 30 bbl of oil (20° gravity) and 600,000 cu ft of gas per day on a 3/8-in. choke; tubing pressure 300 psi; casing pressure 600 psi. The latter well with casing perforated at 2,290-2,302 ft flowed at an initial rate of 25 bbl of oil and approximately 20,000 cu ft of gas daily with tubing pressure 90 psi. At the end of the year the field consisted of 15 Kilpatrick and three Tokio producers.

MCKAMIE-PATTON FIELD

The McKamie-Patton Field, Lafayette County, producing oil, gas and condensate on an east-west anticline from the Smackover limestone (Jurassic) was extended more than one-half mile eastward with the completion on May 4, 1949 of the Atlantic Refining Co. #1 Bodcaw Lumber Co. located 983 ft north 1,270 ft west of the SE corner of Sec. 28, T. 17 S., R. 23 W. The porous Reynolds oolite of the Smackover limestone was topped at 9,196 ft and the well produced from this zone at an initial rate of 112 bbl (67° gravity) condensate per day (basic sediment 1/10 per

cent); tubing pressure 2,160 psi; gas-oil ratio 10,500:1. A dry hole completed Aug. 27, 1949, namely, Bodcaw Oil Co., Inc. #1 A. H. Layman, Tr., 300 ft north of the center SW ¼ Sec. 27, T. 17 S., R. 27 W. bottomed at 9,314 ft limited the productive area on the east edge of the field. Recycling of gas to increase oil and condensate recovery from the Reynolds oolite reservoir was begun during August. A total of 33 wells were producing in McKamie-Patton at the end of the year.

MCNEIL-EAST FIELD

The East McNeil Field in northeast Columbia County, producing only from the Pettit limestone of the Sligo formation (Lower Cretaceous) was enlarged by five of the six wells drilled and completed as producers during 1949. The field lies on an anticlinal nose but the disappearance of porosity and permeability in the reservoir rock limits the productive area. Four of the six wells were drilled by McAlester Fuel Co. and two by Floyd P. Wilson, Tr. Two of the wells completed during the year extended the field one-half mile westward; two others enlarged the west end of the field one-quarter mile northward; and one well extended the field eastward a distance of one-half mile. Seven wells in the field were producing at the end of 1949.

SANDY BEND FIELD

The Sandy Bend Field producing from the Nacatoch sand (Upper Cretaceous) and lenticular Travis Peak (Lower Cretaceous) sands along the high (north) side of a fault was extended about a mile and a quarter eastward by three small producers completed during the year in the Nacatoch sand. Two of the wells were drilled by C. M. Bagley in SW ¼ SE ¼ Sec. 7, T. 18 S., R. 12 W., namely: Trammell #1 and #2, producing from 2,263 to 2,295 ft and 2,282-2,320 ft., respectively (open hole completions). Trammell #1 pumped six B/D and Trammell #2 pumped 20 B/D initially. The other producer drilled during the year, Carl Holloway et al., #1 G. C. Norris 275 ft east 260 ft south of the northwest corner of SW ¼ SW ¼ Sec. 8, T. 18 S., R. 12 W., was an open hole completion between 2,280 and 2,330 ft, and pumped initially eight B/D. Production was being obtained from eight wells in the field as the year ended.

URBANA FIELD

The Urbana Field in Union County which produces from lenticular sands of the Hosston formation (Lower Cretaceous) on a domal anticline (in the old producing area of the field) and from the Meakin and Graves sands (Upper Cretaceous) on a gentle dome at the south end of the field, was enlarged slightly by wells completed in the Meakin sand during 1949. In all, nine wells were completed in the Meakin reservoir as producers during the year, seven of which were drilled by Roberts Petroleum Co. (R. C. Wallingsford). Two of the latter wells, J. R. Winn #A-6 and #A-10 located in NE ¼ SE ¼ NW ¼ and NW ¼ NE ¼ NW ¼ respectively, in Sec. 14, T. 18 S., R. 13 W. enlarged the south end of the field about one-quarter mile eastward. The wells pumped initially 71 and 81 B/D (27° gravity). The Urbana Field contained 80 producers in all (most of them producing from lenticular Hosston sands) at the end of the year.

NORTHWEST ARKANSAS

The fields of northwest Arkansas yield only dry, sweet gas, no oil having been found associated with the gas in this region. Twenty-one fields produce the gas from lenticular sands of the thick Atoka formation (Pennsylvanian) and many of these fields yield gas from multiple zones. One field in this region produces dry gas from the Hale formation (Pennsylvanian). All of the fields of the region lie along faulted anticlines trending in an easterly or northeasterly direction.

The dry or sweet gas production of northwest Arkansas showed an increase, producing 5,703,413 Mcf in 1948 as compared with 6,900,678 Mcf during 1949, a net increase of 1,197,265 Mcf. All of the gas is used for light, fuel and drilling.

The White Oak Field, Franklin County, led all other fields of the region in the annual output for 1949 with 3,615,830 Mcf. Clarksville Field in Johnson County was second with 1,334,068 Mcf. Silex Field, Pope and Johnson Counties with 257,151 Mcf was third largest producer and Massard Prairie, Sebastian County, was in fourth place with 208,933 Mcf.

Two new fields were discovered in northwest Arkansas in 1949, namely, the Cecil Field, Franklin County and the Rudy Field, Crawford County. Only one field in the region, White Oak in Franklin County, was enlarged by wells drilled during the year. Brief descriptions of the new fields and the extension follow:

NEW FIELDS

CECIL FIELD

The discovery well of the Cecil Field, Franklin County, the Arkansas-Louisiana Gas Co. #1 Ralph S. Barton, located in the center of SE ¼ SE ¼ NW ¼ Sec. 27, T. 9 N., R. 28 W., was drilled to 6,650 ft and completed as a producer on Sept. 26, 1949. The hole was plugged back to 4,930 ft and 7-in. casing was set at 4,850 ft. The section from 4,850 to 4,930 ft, comprising sandy limestone and limy sandstone of the Hale formation (Pennsylvanian) was acidized with 5,000 gal and an open hole completion was effected. Initial production from this zone was at the rate of approximately seven Mmcf of gas per day on open flow, rock pressure 1,224 psi. The discovery well was shut-in pending construction of a pipeline connection and no other wells were drilled in the new field during the remainder of the year.

RUDY FIELD

The Rudy Field, Crawford County, about five miles north of Van Buren, Arkansas, was discovered by Sher Developments, Ltd. The first producer, #1 Muggins Hall, located 660 ft south, 300 ft west of the northwest corner SW ¼ NW ¼ Sec. 29, T. 10 N., R. 31 W. was completed May 13, 1949. It was bottomed at 1,592 ft and a packer was set on tubing at 1,338 ft. Dry gas was produced from a sand in the Atoka formation between 1,378 and 1,387 ft (only producing zone in the well) at an initial rate of 650,000 cu ft per day on open flow; rock pressure 460 psi. The well was produced at intervals to furnish fuel for drilling other wells in the new field.

Two additional producers were drilled in the field during the year, namely: (1) Sher Developments, Ltd. #1 Ethel Hicks in SE ¼ NW ¼ SE ¼ Sec. 30, T. 10 N., R. 31 W., bottomed at 1,873 ft and completed in an Atoka sand at 1,840-70 ft, which produced initially 550,000 cu ft of gas daily on open flow, rock pressure 450 psi; and (2) Sher Developments, Ltd. #1 Clarence and Alice Xander in NW ¼ SE ¼ NW ¼ Sec. 29, T. 10 N., R. 31 W. which yielded initially 1,350,000 cu ft of gas per day from Atoka sands in an open hole completion between 1,298 and 1,340 ft; rock pressure 610 psi. A dry hole, Sher Developments, Ltd. #2 Muggins Hall, drilled to 2,214 ft in NE ¼ NE ¼ NW ¼ Sec. 31, T. 10 N., R. 31 W. penetrated a sand lens at 774-780 ft where a good show of gas was noted. All three producers in the new field were shut-in at the end of the year pending construction of a pipeline connection.

EXTENSIONS

WHITE OAK FIELD

The White Oak Field, Franklin County, produces gas from several lenticular sandstones of the Atoka formation (Pennsylvanian) between 960 and 3,750 ft in depth. During the year three producers were completed in the field in this formation. Two of these were dual completions and

the other a single completion. They extended the field only slightly on the north and south sides. Completion records of the three wells follow:

One of the dual completions, Arkansas Western Gas Co. #1 Huggins Estate, 1,320 ft S., 1,320 ft W. of the center of Sec. 15, T. 10 N., R. 27 W., drilled during March, was bottomed at 3,784 ft. The casing was perforated opposite the higher of the two gas sands at 2,540-65 ft, which yielded initially eight Mmcf per day through the annulus. The casing was perforated opposite the lower sand at 3,700-76 ft and the initial output from this zone was two Mmcf per day through the tubing. The well enlarged the proved productive area one-half mile northward in about the center of the field.

The other dual producer completed in 1949, Arkansas Western Gas Co. #1 Guy Patrick, located 660 ft east 1,320 ft north of the center of Sec. 26, T. 19 N., R. 27 W., was drilled 3,241 ft deep during October. The upper of the two gas sands produced through the annulus from perforations between 2,786 and 2,798 ft, at an initial rate of two Mmcf per day. The lower sand produced through the tubing from perforations at 3,140-72 ft, yielding initially 13 Mmcf of gas daily.

The single completion was effected in Sherrod and Apperson #1 Whittson, 1,320 ft east 660 ft north of the southwest corner of Sec. 28, T. 10 N., R. 27 W., drilled in February, 1949 to a total depth of 3,315 ft. The casing was perforated opposite the gas sand at 2,910-20 ft, and the initial output from this zone was estimated at 7-1/2 Mmcf per day.

The two latter wells enlarged the productive area about one-half mile southward in the central part of the field.

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FIG. 1 - GEOPHYSICAL EXPLORATION IN ARKANSAS DURING 1949

TABLE I - OIL AND GAS PRODUCTION STATISTICS FOR ARKANSAS IN 1949

LINE NUMBER	FIELD (County)[A]	PRODUCING FORMATION NAME AND AGE[B]	YEAR OF DISCOVERY	OIL PRODUCTION AREA PROVED ACRES	OIL PRODUCTION BARRELS TO END OF 1949	OIL PRODUCTION BARRELS DURING 1949	GAS PRODUCTION AREA PROVED ACRES	GAS PRODUCTION MILLION CU FT[C] TO END OF 1949	GAS PRODUCTION MILLION CU FT[C] DURING 1949	GAS/OIL RATIO[D] MCF/BBL	CONDENSATE PRODUCTION IN BBL TO END OF 1949	CONDENSATE PRODUCTION IN BBL DURING 1949
	SOUTH ARKANSAS											
1	Atlanta, *Columbia*		1938	2,320	11,832,537	1,078,796	2,320	18,143	2,074			
2		Cotton Valley, Jur	1943	360	307,724	158,756	360[2]	191	128			
3		Reynolds,[3] Jur	1938	2,320	11,524,813	920,040	2,320[2]	17,952	1,946			
4	Bear Creek, *Union*	Reynolds, Jur	1946	360	273,425	213,871	360[2]	14	10			
5	Big Creek, *Columbia*	Reynolds, Jur	1939				160	4,374	Abd 1946		168,327	
6	Bradley, *Lafayette*	Buckrange,[4] U Cre	1925	80	186,705	Abd 1933	x	x				
7	Bragg (Cand), *Ouachita*	Nacatoch, U Cre	1934	10	37,848	Abd 1940	10[2]	x				
8	Buckner, *Columbia & Lafayette*		1937	2,100	8,174,946	776,133	2,100[2]	1,948	131			
9		Hosston, L Cre	1946	1,120	1,009,043	403,023	1,120[2]	46	23			
10		Reynolds, Jur	1937	1,680	7,165,903	373,110	1,680[2]	1,902	108			
11	Cairo, *Union*	Reynolds, Jur	1948	680	728,892	627,140	680[2]	623	532			
12	Calhoun, *Union*	Reynolds, Jur	1944	160	230,757	29,046	160[2]	2,350	333			
13	Champagnolle (Rainbow), *Union*	Graves, U Cre Blossom, U Cre Tokio, U Cre Hosston, L Cre	1927	3,465	16,848,975	257,556	2,464	2,682[9]	218			
14		Reynolds, Jur	1946	20	923	Abd 1946		x				
15	College Hill, *Columbia*	Reynolds, Jur	1948	40	5,755	Abd 1,401[10]	40[2]	1	0.2			
16	Columbia, *Columbia*	Reynolds, Jur	1942				80	215	Shut-in		10,201	Shut-in
17	Cypress Lake, *Miller*	Paluxy, L Cre	1947	300	316,254	120,104	300[2]	69	18			
18	Dorchat-Macedonia, *Columbia*		1939	6,800	4,227,902	471,767	7,200[2]	174,320	16,086		8,925,237	458,255
19		Cotton Valley, Jur	1942	6,800	4,227,902	471,767	6,800[2]	62,681	6,109		2,127,425	147,605
20		Reynolds, Jur	1939	(Included with condensate)			7,200[11]	111,639	9,977		6,797,812	310,650
21	El Dorado, East, *Union*	Nacatoch, Cre U	1922	1,780	10,321,211	96,819	x	x	x			
22	El Dorado, South, *Union*	Nacatoch, Cre U	1920	10,650	50,671,580	239,767	x	3,821[9]	226			
23	Falcon, *Nevada*		1938	40	12,090	3,563						
24		Nacatoch, Cre U	1938	10	136	Shut-in						
25		Tokio, Cre U	1947	20	2,737	Shut-in						
26		Hosston, Cre L	1947	20	9,217	3,563						
27	Felsenthal, *Ashley*	Cotton Valley, Jur	1948	40	303	Shut-in						
28	Fouke, *Miller*		1940	1,100	6,405,938	943,079	1,100[2]	576[17]	173			
29		U Paluxy, Cre L	1940	1,060	6,312,998	915,285	1,060[2]	339	82			
30		L Paluxy, Cre L	1947	60	92,940	27,794	60[2]	237	91			
31		Mooringsport, Cre L	1947	40			40					
32	Garland City, *Miller*	Paluxy, Cre L	1932	370	2,380,292	21,200	x	x				
		Nacatoch, Cre U	1941									
33	Gum Creek, *Ouachita*	Blossom, Cre U	1945	340	535,598	164,519	120	350	287			
		Tokio, Cre U	1945									
34	Hampton, *Calhoun*	Meakin, Cre U	1943	200	112,568	55,686	x	x	x			
35	Heynesville, *Columbia*	Pettit, Cre L	1942	3,420	3,084,906	362,698	3,420[2]	4,851	237			
36	Hibank, *Union*	Nacatoch, Cre U	1942	360	19,010	10,384	40	170	112			
37	Hillsboro, *Union*	Nacatoch, Cre U	1930	1,500	551,033[21]	63,236	x	x	x			
		Hosston, Cre L	1949	20								
38	Irma, *Nevada*	Nacatoch, Cre U	1921	2,160	8,288,170	127,029	x	x	x			
39	Lawson, *Union*	Meakin, Cre U	1935	20	x[22]	Abd 1942	x	x				
40	Lenz, *Miller*	Paluxy, Cre L	1930	20	x[23]	Abd 1941	x	x				
		Glen Rose, Cre L										
41	Lewisville (Stamps), *Lafayette*	Tokio, Cre U	1939	60	817,767	26,644	x	x				
		Hodessa, Cre L	1939	350								
42	Lewisville, West, *Lafayette*	Tokio, Cre U	1946	120	45,920	14,570	x	1				
		Paluxy, Cre L										
43	Lisbon, *Union*	Nacatoch, Cre U	1925	4,300	7,164,301	38,095	x	x				
44	Locust Bayou, *Calhoun*	Meakin, Cre U	1947	40	12,099	6,591						
45	Loutre Creek, *Union*	Reynolds, Jur	1949	40	31,137	31,137	40[2]	16	16			
46	Magnolia, *Columbia*		1938	4,675	59,541,506	4,289,097	4,675	59,736	4,805			
47		Cotton Valley, Jur	1943	400	244,406[26]	116,750	400[2]	509	254			
48		Reynolds, Jur	1938	4,675	59,297,100	4,172,347	4,675[28]	59,227	4,551			
49	Mars Hill, *Lafayette*		1947	40	2,509	358	480	480	75		79,682	23,493
50		Cotton Valley, Jur	1948	40	2,509	358	40[2]	1	.1			
						Abd 1949						
51		Reynolds,[3] Jur	1947	(Included with condensate)			480	479	75		79,682	23,493
52	McDonald, *Ouachita*	Sligo, Cre L	1929	75	117,085	Abd 1932	x	x				
53	McKamie-Patton,[24] *Lafayette*		1940	440	(Included with condensate)		3,400	75,142	9,810		9,458,016	1,129,161
54		Cotton Valley, Jur	1942	40	33,204	Abd 1944	40[2]	[7]				
55		Reynolds, Jur	1940	400	(Included with condensate)		3,400	75,135	9,810		9,458,016	1,129,161
56	McNeil, E., *Columbia*	Sligo, Cre L	1946	280	62,157	37,825						
57	Midway, *Lafayette*	Reynolds, Jur	1942	1,800	19,286,998	2,684,363	1,800[7]	6,402	988			
58	Mount Holly, *Union*	(Incl. W. Mt. Holly)	1941	1,300	1,720,300	116,255	1,300[13]	4,182	135			
59		Cotton Valley, Jur	1943	40	15,344	Abd 1944	40[2]	[7]				
60		Reynolds, Jur	1941	1,300	1,704,956	116,255	1,300[13]	4,175	135			

LINE NUMBER	NUMBER OF WELLS[6]			WELLS PRODUCING[7] DEC. 1949			RESERVOIR PRESSURE LB PER SQ INCH		SECONDARY RECOVERY[8]	CHARACTER OF OIL[A]		PRODUCING FORMATION					DEEPEST ZONE TESTED[N] TO END OF 1949	
	COMPLETED TO END 1949	1949		OIL		GAS	INITIAL	AVG./END 1949		GRAVITY A.P.I.	SULPHUR PER CENT	CHARACTER[I]	POROSITY PER CENT[J]	DEPTH TO TOP OF PRODUCING ZONE FT[K]	PROD. THICKNESS AVG. FT / NET	STRUCTURE[M]	NAME	DEPTH OF HOLE, FT
		COMPLETED	ABANDONED	FLOWING	ARTIFICIAL LIFT													
1	62	3	4	23[4]	34[5]												Eagle Mills, Jur	9,177
2	58[5]	4[6]		4[6]	10[6]		3,085	2,520		41-48	0.29	S	15-20	6,780	12	A L		
3	58[5]			19[6]	24[6]		3,821	2,478	W[9]	40-43	0.49	O L	15	8,200	27	A		
4	6	4		2	7		2,750	x		29	2.25	O L	18.2	6,330	15.5	A	Smackover, Jur	6,588
5	2						3,725	x		66	0.05	O L	12.5	7,956	30	A	Smackover, Jur	7,999
6	6						x	x		26	0.43	S	x	2,785	5	A	Smackover, Jur	11,440
7	1						x	x		16	2.56	S	25	1,356	13	M L	Hosston, L Cre	2,500
8	58	6		1	50									4,640			Smackover, Jur	7,444
											.62-			4,710				
9	29	6		1	26		2,084	2,010		27-40	.68	S	20-25	4,800	26[8]	A L		
														4,990				
10	29				24		3,195	x		32	1.87	O L	20	7,200	30	A		
11	16	9		16			3,275	3,166		35-39	0.9	O L	17	7,740	31	A	Smackover, Jur	8,136
12	4			3			3,450	x		50	0.22	O L	16	8,260	26	A	Smackover, Jur	8,312
													32	2,580	10			
													30	2,690	7			
13	270	6	4		62		x	x		22-34	1.4-2	S	25	2,780	20	A L	Eagle Mills, Jur	6,911
													32-34	2,990	8			
14	1						x	x		17	3.9	O L	x	5,640	2	A		
15	1		1				x	x		34	x	O L	15	6,530	5	A	Smackover, Jur	6,539
16	2						3,750	3,035		65	0.14	O L	18	8,030	25	A	Smackover, Jur	8,150
														3,900	10			
17	12	1			12		1,775	1,500		32-34	1.2	S	22	3,970	6	M L F	Bodessa, L Cre	5,010
														3,990	9			
18	99[12]	14[14]	11[14]	62[13]	12[13]	86[13]											Smackover, Jur	9,038
19	120[13]	12[14]	11[14]	62[13]	12[13]	45[13]	3,615	x		38-72	.02-.43	S	15	6,680	30	A L		
20	64[13]	2[14]	Incl w/gas			41[13]	4,243	2,005		43-62	.13-.39	O L	14	8,800	36	A		
21	211				35		x	x		20	1.9	S	25	2,170	6	T L	Cotton Valley, Jur	6,003
22	1,120	3	3		125		x	x		33	1.1	S	25	2,200	13	T L	Smackover, Jur	7,802
23	4	1[15]			1												Smackover, Jur	6,068
24	2				0[16]		x	x		14	3.3	S	x	1,180	10	A F		
25	1				0[16]		x	x		15	x	S	18	2,106	9	A F		
26	1	1[15]			1		x	x		30	x	S	20	3,110	8	A F		
27	1				1		x	x		23	x	S	22	5,870	6	D	Smackover, Jur	6,170
28	54				51												Smackover, Jur	9,550
							1,485-							4 sands				
29	49				49[16]		1,326	x		29-34	1.3	S	25-29	3,400-	22	M L F		
														3,700				
														4,300	6			
30	3				1		x	x		34	x	S	15-20	4,330	8	M L F		
														4,400	10			
31	2				1[16]		x	x		42-44	x	S	18-25	4,540	12			
														4,600	5	M L F		
32	28				8		x	x		31	1.2	S	27	2,925	7	M L	Smackover, Jur	7,906
													29.7	1,590	15			
33	28	1[18]	2		17[16]	1	x	x		16-24	1.7	S	30-31	2,255[19]	17	d L F	Smackover, Jur	6,264
													25.6	2,470	14			
34	9				8[16]		x	x		14-15	5.0	S	25	2,480	24	A F	Smackover, Jur	4,420
35	34			33	1		2,344	540	G W	39	0.6	L	18	5,400	9.4	A	Hosston, Cre L	5,704
36	13	7	2		9	1	x	x		37-41	.6	S	31[20]	2,080	x	M F	Smackover, Jur	7,465
37	48	3	1		32		x	x		23	x	S	20	2,230	7	A	Hosston, Cre L	4,011
	1	1			1		x	x		34	x	S	18	3,940	4	A L		
38	150				70		x	x		14	2.7	S	25	1,150	27	M F	Hosston, Cre L	3,728
39	2						x	x		24	x	S	x	2,670	8	A	Smackover, Jur	6,765
40	2						x	x		29-47	x	S	x	2,845	5	L	Smackover, Jur	7,310
														4,210				
41	3	2			3		x	x		17-20	x	S	25	2,290	16	M F	Smackover, Jur	7,420
	18		2		15		1,365	x		39-42	0.6	L	17-22	3,400	10			
42	3	1[15]			2		x	x		18	x	S	25	2,480	7	M F	Bodessa, Cre L	4,400
										28	x	S	20	3,930[24]	5	M L F		
43	359	3[25]			111		x	x	W	34	1.08	S	25	2,100	11.6	T L	Smackover, Jur	6,861
44	2				2		x	x		15	x	S	18	1,990	5	A	Ozan, Cre U	2,048
45	1	1			1		3,401	x		41	.5	O L	17	7,770	11	A	Smackover, Jur	8,010
46	130	5		87	28[27]												Smackover, Jur	8,205
														5 sand				
47	10	2		84	6		2,750	x		42-50	0.2-0.6	S	15-20	lenses	5-16	A L		
														between				
														5,450-				
														6,790				
48	120	3		3	22		3,465	2,743	P W	38	0.9	O L	16.8	7,500	93.4	A		
49	4		3		1											A	Smackover, Jur	9,178
50	1		1				x	x		44	x	S	16	7,660	8	A L		
51	3		2				2,350	x		47-59	.2	O L	15	9,030	15	A		
52	6						x	x		30	x	S	20	2,800	7	M F	Hosston, Cre L	3,378
53	36	1		5	6	22											Eagle Mills, Jur	9,980
54	1						2,841	x		43.6	0.38	S	16	7,255	12	A L		
55	35	1		5	6	22	4,380	3,200	P G	43-47	0.2-0.6	O L	15.1	9,100	90[29]	A		
56	7	5			7		x	x		27-30	x	L	x	3,490	8	N L	Smackover, Jur	6,227
57	45			30	15		2,920	2,710	P W	36	1.3	O L	26	6,400	81	A	Smackover, Jur	6,750
58	15				11												Smackover, Jur	7,373
59	2						x	x		41	0.27	S	18	6,110	6			
60	13				11		3,180	2,995		43	0.77	O L	20	7,140	17			

TABLE 1 - Continued OIL AND GAS PRODUCTION STATISTICS FOR ARKANSAS

LINE NUMBER	FIELD (County)[a]	PRODUCING FORMATION NAME AND AGE[b]	YEAR OF DISCOVERY	OIL PRODUCTION			GAS PRODUCTION			GAS/OIL RATIO[d] MCF/BBL	CONDENSATE PRODUCTION IN BBL	
				AREA PROVED ACRES	BARRELS TO END OF 1949	BARRELS DURING 1949	AREA PROVED ACRES	MILLION CU FT[c] TO END OF 1949	MILLION CU FT[c] DURING 1949		TO END OF 1949	DURING 1949
61	New London, *Union*	Cotton Valley, Jur	1942	920	2,295,986	199,664	920[e]	1,114	93			
62	Nick Springs, *Union*		1940	50	791,543	9,686	x	x				
63		Hosston, Cre L	1940	40	785,526	9,686						
64		Cotton Valley, Jur	1943	10	6,017	Abd 1944	x	x				
65	Pace City, *Ouachita*		1946	320	414,035	99,207	280[e]	49	12			
66		Meakin, Cre U	1947	60								
67		Sligo, Cre L	1946	280	414,035	99,207	280[e]	49	12			
68	Pine Tree, *Columbia*	Reynolds, Jur	1949	120	99,762	99,762	120[e]	150	150			
69	Rodessa Ext., *Miller*	Rodessa, Cre L	1937	2,300	7,902,245	152,298	2,300[e]	35,838	924			
70	Rodessa Ext. North (Risinger) *Miller*	Rodessa, Cre L	1943				1,000	6,001	753		77,543	4,047
71	Salem Church, *Union & Columbia*	Reynolds, Jur	1944	20	(Included with condensate)		640	4,018	1,874		117,932	51,250
72	Sandy Bend, *Union*		1945	120	33,991	16,232						
73		Nacatoch, Cre U	1945	60								
74		Hosston, Cre L	1947	60	33,891	16,232						
75	Schuler, *Union*		1937	4,200	62,134,822	3,070,041	4,200[e]	136,112	13,319			
76		Cotton Valley, Jur	1942	640	2,679,986	114,121	640[e]	4,636	134			
77		Morgan (Cotton Valley)	1937	500	3,444,359	83,331	500[e]					
78		Jones(Cotton Valley)Jur	1937	4,200	48,830,419	2,678,029	4,200[e]	116,903	11,884			
79		Reynolds, Jur	1937	1,100	7,180,058	194,560	1,100[e,f]	14,573	1,301			
80	Schuler, East, *Union*	Cotton Valley, Jur	1941	460	1,102,079	66,397	460[e]	1,302	34			
81	Smackover, *Ouachita & Union*			29,500	422,665,172	3,900,867	29,500[e]	6,543[g]	555			
82		Nacatoch, Cre U	1922	20,000								
83		Meakin, Cre U	1923	3,000								
84	"Heavy Oil"	Graves, Cre U	1925	10,230	363,458,538	3,449,252	29,500[e]	6,543[g]	555			
85		Blossom, Cre U	1925	12,190								
86	"Light Oil" (Louann)	Meakin, Cre U	1922	9,880	58,737,274	426,271						
87	Snow Hill area	Reynolds, Jur	1936	400	469,360	25,344						
88	Spirit Lake, *Lafayette*			440	1,261,281	371,315	400[e]	895	212			
89		Buckrange, Cre U	1948	20	3,663	617 Abd 1949						
90		Goodland, Cre L	1949	40	11,475	11,475						
91		Paluxy, Cre L	1947	120								
92		Mooringsport, Cre L	1947	100	564,027	205,670	240[e]	330	102			
93		Rodessa(Hill) Cre L	1948	20								
94		Rodessa(Kilpatrick)Cre L	1946	360	682,116	153,553	360[e]	565	110			
95	Spottsville, *Columbia*	Reynolds, Jur	1949	160	3,675	3,675	160[e]	53	53			
96	Stephens, *Columbia, Ouachita, & Nevada*		1922	18,000	19,114,415	1,612,410	0[e,i]					
97		Nacatoch, Cre U	1923									
98	Shallow[j,k]	Buckrange, Cre U	1922	17,500[j,k]	8,261,485	199,496						
99		Tokio, [42] Cre U	1942	2,680								
100	Deep (Chart Area)	Glen Rose, [43] Cre L	1941	1,600	10,525,321	1,148,900						
101		Hosston, [41] Cre L	1941	1,290								
102	Hogg Sand	Pine Island, Cre L	1949	350	199,288	199,288						
103	Curry Area (In graben)	Hosston, [47] Cre L	1949	160	45,765	45,765						
104	North Ext. (In graben)	Glen Rose, [42] Cre L[e]	1949	40	7,179	7,179						
105	North Stephens	Buckrange, Cre U	1945	200	75,377	11,782						
106	Strong, *Union*		1944	80	56,704	4,131						
107		Cotton Valley, Jur	1945	40	28,307	4,131						
108		Reynolds, Jur	1944	40	29,397	Abd 1946						
109	Texarkana, *Miller*	Reynolds, Jur	1942				640	4,603	1,044		140,232	32,526
110	Troy, *Nevada*	Nacatoch, Cre U	1936	790[e,l]								
111		Tokio, Cre U	1936	830	4,768,881	314,161	x	x				
112	Urbana, *Union*		1930	1,600	9,930,881	270,488	x	57	50			
113		Nacatoch, Cre U	1930	200								
114		Meakin, Cre U	1948	800	7,845,008	203,737	x	57[45]	50			
115		Graves, Cre U	1930									
116		Hosston(Exc. Crain) Cre L	1930	1,000								
117		Hosston (Crain Sd)Cre L	1940	230	2,075,873	66,751						
118	Village, *Columbia*		1938	2,400	10,366,525	1,843,815	2,400[e,f]	24,873	3,447			
119		Glen Rose (Sligo) Cre L	1949	40	21,888	21,888		4	4			
120		Hosston, Cre L	1946	1,000	2,299,328	930,497	1,000[e]	3,604	1,684		(Inc. with oil)	
121		Cotton Valley, Jur	1946	360	563,984	173,548	360[e]	632	116		(Inc. with oil)	
122		Reynolds, Jur	1938	1,680	7,481,325	717,882	1,680[e]	20,633	1,643		(Inc. with oil)	
123	Warnock Springs, *Columbia*	Reynolds, Jur	1946	(Included with condensate)			800	2,724	1,344		107,049	56,974
124	Warnock Springs Ext., *Columbia*	Reynolds, Jur	1949				160	Shut-in			(Shut-in during year)	
125	Wesson, *Ouachita*		1945	1,800	8,626,867	3,066,191	1,800[e]	1,842	672			
126		Nacatoch, Cre U	1946									
127		Buckrange, Cre U	1947	160	100,398	61,558	160[e]	(Incl. with Hosston)				
128		Blossom, Cre U	1949									
129		Tokio, Cre U	1946	150	158,896	71,710	150	(Incl. with Hosston)				
130		Glen Rose(Exc. Hogg) Cre L	1945	760	2,542,541	674,802	760	(Incl. with Hosston)				
131		Hogg Sand, Cre L	1946	1,540	4,640,178	1,923,371	1,540[e]	505	228			
132		Hosston, Cre L	1946	260	1,184,854	334,750	320[e]	1,337	444			

LINE NUMBER	NUMBER OF WELLS[6]			WELLS PRODUCING[7] DEC. 1949			RESERVOIR PRESSURE LB PER SQ INCH		SECONDARY RECOVERY[8]	CHARACTER OF OIL[9]		PRODUCING FORMATION					DEEPEST ZONE TESTED[10] TO END OF 1949	
	COMPLETED TO END 1949	1949		OIL		GAS	INITIAL	AVG./END 1949		GRAVITY A.P.I.	SULPHUR PER CENT	CHARACTER[1]	POROSITY PER CENT[11]	DEPTH TO TOP OF PRODUCING ZONE FT.	PROD. THICKNESS AVG. FT. NET	STRUCTURE	NAME	DEPTH OF HOLE, FT.
		COMPLETED	ABANDONED	FLOWING	ARTIFICIAL LIFT													
61	19				13[12]		2,590	x		30	1.8	S	22	4 lenses 5,320-5,850	31	A	Smackover, Jur	6,100
62	15				5[12]												Smackover, Jur	6,819
63	14				5[12]		1,600	x		37	0.9	S	31	3,150	18	M L F		
64	1						x	x		36	x	S	23	4,800	3	M L F		
65	16				16												Hosston, Cre L	3,726
66	2				2		x	x		31	x	S	15	2,190	12	M F		
67	14				14		x	x		28-33	1.32	S	28	3 lenses 2,750-2,830	7	M L F		
68	3	3		2	1		3,000	2,705		44	x	O L	19	8,400	20	A	Smackover, Jur	8,497
69	123				52		2,800	x		39-45	0.34	S L	20	6,050	15	A F	Bodessa, Cre L	6,514
70	3					3	1,160	x		54-75	x	S	21	5,890	10	A F	Bodessa, Cre L	6,997
71	4			1		3	3,135	2,726		39-71	.04-.25	O L	20	6,980	24	A	Smackover, Jur	7,090
72	9	3	1		8												Hosston, Cre L	3,602
73	6	3			6		x	x		19-27	x	S	30[20]	2,260	25	M L F		
74	3		1		2		x	x		28	1.3	S	25	3,110[24]	15	M L F		
													20	3,500	8			
75	206[33]		1	119	49												Smackover, Jur	8,328
76	24[33]		1		25		3,090	x		45-47	x	S	16	6,900	18	A L		
77	14[33]				12		2,250	x		41-42	0.5	S	16	5,500	25	A L		
78	151[33]			118	6		3,520	1,622	P G W	34	1.5	S	18	7,530	34	A		
79	17[33]			1	6[12]		3,550	x		38	0.9	O L	20	7,600	26	A		
80	6			2	2		2,509	2,044		45-47	0.36	S	25	5,580	14	A L	Smackover, Jur	7,702
81	3,810	17	6		1,902											D T	Igneous	7,973
82														1,920	19	D T L		
83														2,230	8	D		
84	x	17	6		x		x	x		19-23	2-2.3	S	25	2,380	20	D		
85														2,530	13[36]	D T L		
86	x				x		x	x		27	2.2	S	25	2,250	9	T L		
87	6				2		x	x		36	1.1	O L	24	4,800	19	D		
88	22	1	1	4	16												Bodessa, Cre L	4,654
89	1		1		Abd 1		x	x		19	1.6	S	25	2,650	11	M F		
90	1	1		1			x	x		36	x	L	x	3,600	10	M F		
91													25-30	2 sands 3,580-3,700	16-8	M L F		
92	11			3[37]	7		425-1,645	x		33-42	x	S	25	3,730	15	M L F		
93													18	4,120	30	M F		
94	9				8		1,785	x		38	1.0	L	20	4,100	20	M F		
95	1	1		1			3,165	3,125		45	.5	O L	16	7,740	50	A	Smackover, Jur	7,876
96	531	67[46]	16		407												Smackover, Jur	6,387
97										13	2.8	S	x	1,500	15	T L F		
98	330	21	6		243		x	x		30	1.6	S	26	2,100	5			
99										17-28		S	25	2,350	14			
100	167	22	9		134		x	x		30.5	1.5-2.2	S L	28	2,650	8	A F		
101										32		S	30	3,040	19			
102	14	14			14		1,308	416	U[42]	34	x	S	28	2,970	15	M L F		
103	8	8			8		x	x		30-33	x	S	22	3,320	16	M L F		
104	2	2			2		x	x		28	x	S	22	2,930	12	M L F		
105	10		1		6		x	x		26	2.3	S	20	1,990	6	M L F		
106	2				1												Smackover, Jur	6,382
107	1				1		1,280	x		31	x	S	25	4,810	12			
108	1						2,265	x		36	0.95	O L	20	6,320	17			
109	2					2	3,396	3,003		70	0.3	O L	14	7,350	51	A	Smackover, Jur	7,700
110										14	2.2	S	25	1,220	13	M F		
111	78	1			64		x	x		22	2.5	S	30	2,150	15		Eagle Mills, Jur	6,143
112	94	10															Smackover, Jur	6,520
113										32	x	S	30[48]	2,300	x	T L		
114	73	10			62	1[37]	x	x		28	x	S	25	2,500	8	A		
115										(No oil prod)		S	15	2,620	3	A		
116										19-26	1.4	S	20	3,200-3,500	9	A L		
117	21				16[16]		x	x		30	x	S	20	3,000	7	A L		
118	82[49]	5[53]		51[4]	34[50]	7[4]											Smackover, Jur	7,603
119	1	1			1		x	x		30	.8	L S	16	3,990	9	A L		
120	45[4]	2		28[4]	7	7[4]	1,800	1,350		33-70	0.4-0.8	S	23	11 sands 4,150	67	A L		
121	13[4]	1	1	7[4]	4		x	x		42-65	0.37	S	20	8 sands 5,430	48	A L		
122	49[4]	1		21[4]	22		3,350	x		40-53	0.8	O L	22	7,320	15	A		
123	5					5[37]	2,900	2,800		48-62	0.1	O L	17	7,350	27	A	Smackover, Jur	7,500
124	1	1				1	2,813	2,813		68	x	O L	16	7,394	7[4]	A	Smackover, Jur	7,403
125	165	14[52]			149	2											Smackover, Jur	6,238
126	11	2								15	2.8	S	20	1,500	6	M L F		
127	12[51]	6[51]			23	2	x	x		29-34	x	S	26	2,150	10	M F		
128	7[51]	7[51]								30	x	S	20	2,200	8	M L F		
129	9	1			8		x	x		19-21	x	S	25	2,340	11	M F		
130	38	2			35		x	x		25-39	1.5-2.0	S L	23	2,590	20	M L F		
131	72	1			70		1,280	469	P W	32	1.6	S	32	3,150	19	M L F		
132	16	1			13		1,315	x		31-40	1.5	S	25	11 sands 3,220	40	M L F		

TABLE 1 - Continued OIL AND GAS PRODUCTION STATISTICS FOR ARKANSAS

LINE NUMBER	FIELD (County)[4]	PRODUCING FORMATION NAME AND AGE[5]	YEAR OF DISCOVERY	OIL PRODUCTION AREA PROVED ACRES	OIL PRODUCTION BARRELS TO END OF 1949	OIL PRODUCTION BARRELS DURING 1949	GAS PRODUCTION AREA PROVED ACRES	GAS PRODUCTION MILLION CU FT[6] TO END OF 1949	GAS PRODUCTION MILLION CU FT[6] DURING 1949	GAS/OIL RATIO MCF/BBL	CONDENSATE PRODUCTION IN BBL TO END OF 1949	CONDENSATE PRODUCTION IN BBL DURING 1949
133	Wilks, *Union*	Reynolds, Jur	1944	40	10,075	Abd 1944	40[7]	88				
134	Wilmington, *Union*	Graves, Cre U	1943	60	75,131	8,262						
135	Woodley (Grimes), *Union*	Nacatoch, Cre U	1922	240	108,280	12,376						
	Total South Arkansas			115,535	765,834,251	28,029,707	78,069	586,728	60,802		19,084,219	1,755,706
	NORTHWEST ARKANSAS											
136	Aetna, *Franklin*	Atoka, Pen	1928				200	782	Shut-in			
137	Alma, *Crawford*	Atoka, Pen	1916				700	13,467	41			
138		Shallow	1916				x	4,639	22			
139		Deep	1922				x	8,828	19			
140	Alma, East, *Crawford*	Atoka, Pen	1924				300	1,958	Abd 1948			
141		Deep	1924				x	1,294				
142		Shallow	1926				x	206				
143		Stray	1926				x	458				
144	Beverly, *Sebastian & Franklin*	Atoka, Pen	1937				625	1,774	97			
145	Blosser, *Sebastian*	Atoka, Pen	1945				160	24	9			
146	Cecil, *Franklin*	Hale, Pen	1949				640	(Disc. & Shut-in 1949)				
147	Clarksville, *Johnson*	Atoka, Pen	1926				1,770	40,422	1,334			
148		Self					x	x	x			
149		Bynum					x	x	x			
150		Hudson No. 1					x	x	x			
151		Houston					x	x	x			
152		Hudson No. 2					x	x	x			
153		Russell					x	x	x			
154		Patterson					x	x	x			
155		Qualls					x	x	x			
156		Kelly					x	x	x			
157		Hudson 2-A					x	x	x			
158	Coal Hill, *Johnson*	Atoka, Pen	1930				200	458	Abd 1947			
159	Ewing, *Sebastian*	Atoka, Pen	1936				650	685	64			
160		Deep					x	452	64			
161		Shallow					x	233	Abd 1948			
162	Greenwood Junction, *Crawford*	Atoka, Pen	1927				350	740	2			
163	Kibler, *Crawford*	Atoka, Pen	1915				2,500	25,345	98			
164		Deep					x	x	90			
165		Shallow					x	x	8			
166	Lavaca, *Sebastian*	Atoka, Pen	1921				1,600	2,569	86			
167		Shallow	1921				x	453	86			
168		Deep	1928				x	2,116	Abd			
169	Mansfield, *Sebastian & Scott*	Atoka, Pen (4 sands)	1902				300	3,471	64			
170	Massard Prairie, *Sebastian*	Atoka, Pen (2 zones)	1904				x	34,961	209			
171	Ozark, *Franklin*	Atoka, Pen	1930				1,000	4,724	128			
172		Deep	1930				x	2,258	104			
173		Anderson	1937				x	1,775	8			
174		Shallow	1938				x	691	16			
175	Rudy, *Crawford*	Atoka, Pen	1949				120	(Disc. & Shut-in 1949)				
176	Section 10, *Crawford*	Atoka, Pen	1920				500	2,128	66			
177	Shibley, *Crawford*	Atoka, Pen	1926				500	2,338	27			
178		NW of fault	1926				x	860	Abd 1948			
179		SE of fault	1927				x	1,478	27			
180	Silex, *Pope & Johnson*	Atoka, Pen	1942				160	816	257			
181		2,500 ft	1942				x	x	x			
182		2,800 ft	1942				x	x	x			
183	Yates Island, *Pope*	Atoka, Pen	1929				1,200	5,016	430			
184	Vesta, *Franklin*	Atoka, Pen	1932				800	2,602	101			
185	White Oak, *Franklin*	Atoka, Pen	1943				6,600	11,170	3,616			
186		Shallow	1943				640	x	x			
187		2,600 ft	1943				3,200	x	x			
188		3,000 ft	1943				6,400	x	x			
189		3,600 ft	1945				1,920	x	x			
190	Williams, *Crawford*	Atoka, Pen	1918				3,800	42,410	271			
191		Deep	1919				x	x	196			
192		Shallow	1918				x	x	75			
	Total Northwest Arkansas						24,675	197,860	6,900			

[1] The gas cap in the Reynolds oolite covered 850 acres but gas is produced with oil over entire area.
[2] Gas is produced over entire area.
[3] The Reynolds oolite is the productive zone of the Smackover limestone.
[4] Each completion counted separately for dual completions.
[5] In addition three wells were shut-in at the end of 1949. Also seven old wells were recompleted in Cotton Valley sand lenses and three old wells were recompleted in the Smackover lime in 1949.
[6] Water injection in one salt water disposal well.
[7] A sand at the base of the Ouan formation.
[8] The four overlapping sand lenses have a total effective thickness of 26 ft but average about ten ft over 1,120 acres.
[9] Cumulative gas prior to 1940 not available.
[10] Abandoned June, 1949.
[11] Out of the total 7,200 acres, 6,000 acres produce mainly gas.
[12] There were 99 bore holes (mostly dual completions) 92 of which were producing in December, 1949.
[13] Counting each completion in dual completions separately.
[14] Recompletions of old wells and one new dual completion, each completion counted separately.
[15] A recompletion.
[16] Also, one well shut-in.
[17] Cumulative gas prior to 1946 not available.
[18] One well drilled and completed in 1949 and five old wells recompleted.

LINE NUMBER	NUMBER OF WELLS[4] COMPLETED TO END 1949	1949 COMPLETED	1949 ABANDONED	WELLS PRODUCING[4] DEC. 1949 OIL FLOWING	OIL ARTIFICIAL LIFT	GAS	RESERVOIR PRESSURE LB PER SQ INCH INITIAL	AVG.-END 1949	SECONDARY RECOVERY[6]	CHARACTER OF OIL[5] GRAVITY A.P.I.	SULPHUR PER CENT	PRODUCING FORMATION CHARACTER[7]	POROSITY PER CENT[7]	DEPTH TO TOP OF PRODUCING ZONE FT	PROD. THICKNESS AVG. FT NET	STRUCTURE[8]	DEEPEST ZONE TESTED[9] TO END OF 1949 NAME	DEPTH OF HOLE, FT
133	1									44	0.2	O L	16	7,850	24	A	Smackover, Jur	7,944
134	2						x	x		17	x	S	25	2,770	16	A	Smackover, Jur	5,836
135	27				22		x	x		20	1.9	S	20	2,200	12	A F	Hosston, Cre L	4,006
	8,103	200[35]	60	442	3,143	135												
136	2					0[37]	640	120				S	x	1,675	x	A	Atoka, Pen	1,678
137	23					7										A	Atoka, Pen	2,916
138	8					4	330	45				S	x	2,065	7			
139	13					3	425	32				S	x	2,600	20			
140	7															A	Atoka, Pen	3,017
141	4						378	36				S	x	2,400	20			
142	2						300	40				S	x	1,880	7			
143	1						425	100				S	x	2,430	4			
144	5					4	440	310				S	x	2,590	12	A	Atoka, Pen	2,700
145	1					1	250	245				S	x	2,730	x	A	Atoka, Pen	2,953
146	1	1				0[37]	1,224	1,224				L S	14	4,850	56	A	Everton, Ord	6,650
147	13					8							11-17			A F	Arbuckle, Ord	6,110
148	2					x	x	580				S	x	1,075	10			
149	1					x	x	700				S	x	1,990	8			
150	1					x	x	300				S	x	2,215	32			
151	1					x	x	380				S	x	2,440	19			
152	1					x	x	386				S	x	2,510	11			
153	5					x	x	393				S	x	2,760	21			
154	1					x	x	340				S	x	2,995	41			
155	2					x	x	490				S	x	3,010	31			
156	5					x	x	450				S	x	3,040	25			
157	2					x	x	1,200				S	x	3,400	30			
158	2						500	Abd				S	x	1,960	x	A	Atoka, Pen	5,596
159	4					4										A	Atoka, Pen	2,850
160	4					4	275	241				S	x	x	15			
161	x						250	x				S	x	x	4			
162	7					4	210	26				S	x	2,300	7	A	Atoka, Pen	2,380
163	40					12										A F	Atoka, Pen	2,775
164	x					11	265	39				S	x	2,285	15			
165	x					1	220	41				S	x	1,260	18			
166	15					13										A	Atoka, Pen	3,092
167	2					2	285	132				S	x	x	4			
168	13					11	280	245				S	x	1,775	15			
169	17					13	x	135				S	x	862-2,200	x	A	Atoka, Pen	2,977
170	93					49	x	8				S	x	1,100-2,260	25	A	Atoka, Pen	6,350
171	11					8										A	Atoka, Pen	5,755
172	5					5	875	230				S	x	3,760	18			
173	3					2	640	104				S	x	2,170	12			
174	3	3				1	670	112				S	x	1,820	12			
175	3	3				0[34]	610-460	610-460				S	x	3 sands 1,300-1,870	30	A	Atoka, Pen	2,214
176	4					4	265	94				S	x	2,440	15	A F	Atoka, Pen	2,596
177	6		4			2										A F	Atoka, Pen	2,630
178	4		4				237	32				S	x	1,245	8			
179	2					2	194	91				S	x	2,630	8			
180	3					1										A F	Boone, Mis	4,120
181	1					x	x	x				S	26	2,475	37			
182	2					x	x	540				S	26	2,800	15			
183	4					3	x	250				S	x	1,030	30	A F	Atoka, Pen	4,575
184	9					9	525	178				S	x	2,270	x	A	Atoka, Pen	2,900
185	19[5]					19[5]										A F	Bloyd, Pen	4,873
186	2					2	x 595	280-490				S	20	960-1,320	20			
187	4					4	954	840				S	x	2,640	20			
188	11					11	966	734				S	x	3,015	30			
189	2					2	1,510	1,200				S	x	3,650	10			
190	64					25										A F	Atoka, Pen	2,585
191	x					20	288	44				S	x	2,150	36			
192	x					5	337	61				S	x	1,315	90			
	353	7	4			186												

[18] Three Blossom sand stringers were productive; the lowest is topped at 2,360 ft.
[21] Permeability very low.
[31] Prior to 1940 production included in El Dorado, East.
[32] Production figures included with El Dorado, East (estimated at 3,500 bbl).
[33] Production less than 1,000 bbl.
[34] One well produced from a Paluxy sand lens at 3,820 ft and another produced from a zone in the Bodessa at 3,990 ft for short periods; both reservoirs have been abandoned.
[35] One of which is a water injection well.
[36] A negligible amount of 53° gravity condensate was produced and is included with oil.
[37] Also, one Cotton Valley and two Reynolds oolite producers shut-in.
[38] Area of gas cap is about 1,400 acres but gas is produced thru area proved for oil.
[39] Basal formation, Glen Rose sub-group. Insignificant oil output reported from a Hosston sand lens. McKamie (eastern part of field) yields mainly gas; Patton (western part) yields oil.
[41] Average thickness oil zone 23 ft.
[51] Gas cap covers 517 acres.
[52] In addition three wells shut-in.
[53] Includes recompletions.
[54] An oil sand (lens) at 2,890 ft was abandoned during year.
[55] The gas cap covered 520 acres.
[56] Thickness so variable, estimate is highly speculative.

TABLE 1 FOOTNOTES - *Continued* - ARKANSAS

[57] One well (gas) shut-in.
[58] Includes E. Stephens.
[59] From isopach map (not based on number of producers as formerly).
[60] Insignificant amount of gas.
[61] Unitization for water injection nearing completion.
[62] Two sands.
[63] Multiple sand lenses.
[64] Surface productive area approximately 1,000 acres.
[65] Gas production is from Graves sand, is used locally; no figures available prior to 1948.
[66] In addition, the following recompletions were effected in 1949: one Nacatoch, six Buckrange, two Tokio, 12 Glen Rose, nine Hosston.
[67] Gas cap covered 880 acres in Reynolds; three gas sands (lenses) in Hosston cover several hundred acres.
[68] Permeability very low.
[69] Bore holes some of which were dually completed.
[70] In addition, ten wells were shut-in at end of 1949.
[71] Six wells produce from Buckrange and Blossom thru same string casing.
[72] In addition, three wells were recompleted in Glen Rose sands and three in Hosston sands in 1949.
[73] Also, three wells were recompleted in Hosston sands, three in Cotton valley sands and one in the Reynolds oolite in 1949.
[74] Three wells shut-in pending pipe line connection.
[75] Only 185 bore holes but 200 counting each completion separately for dual completions.

TABLE 2 - SUMMARY OF DRILLING OPERATIONS IN ARKANSAS

IMPORTANT WILDCATS DRILLED IN 1949

LINE NUMBER	COUNTY OR LOCALITY	LOCATION SEC.	TWP.	RGE.	TOTAL DEPTH, FT. OR METERS	FORMATION	DEEPEST HORIZON TESTED	DRILLED BY	INITIAL PRODUCTION PER DAY OIL, U.S. BBL.	GAS, MILLIONS CU. FT.	CONDENSATE U.S. BBL.	CHOKE, FRACTIONS OF AN INCH	TUBING PRESSURE, LB. PER SQ. IN.	REMARKS
		SURVEY	LAT.	LONG.										
1	Arkansas	24	4 S	2 W	4,183	Quaternary	Paleozoic	J. Lee Youngblood						D & A 11-6-49
2	Bradley	2	16 S	9 W	4,710	Claiborne, Eoc	Eagle Mills, Jur	A. J. Slagter, Jr.						D & A 8-25-49
3	Calhoun	15	15 S	14 W	3,316	Alluvium, Recent	Cotton Valley, Jur	Carter Oil Co.						D & A 6-27-49
4	Calhoun	9	14 S	13 W	3,622	Quaternary	Cotton Valley, Jur	Crown Central Pet. Co.						D & A 4-16-49
5	Cleveland	2	11 S	11 W	3,714	Jackson, Eoc	Paleozoic	Hyman Ginsberg						D & A 7-7-49
6	Columbia	25	19 S	22 W	2,855	Alluvium, Recent	Ozan, U. Cre.	J. A. Funston, et al						D & A 2-28-49
7	Columbia	3	16 S	20 W	3,760	Claiborne, Eoc	Hosston, L. Cre	Marvin A. Green, et al						D & A 10-29-49
8	Columbia	20	18 S	19 W	8,476	Claiborne, Eoc	Smackover, Jur	Lion Oil Co.	650	.72		1/4	900	Discovery well Pine Tree Field
9	Columbia	2	16 S	20 W	3,705	Claiborne, Eoc	Hosston, L. Cre	McAlester Fuel Co.						D & A 12-7-49
10	Columbia	6	18 S	18 W	7,876	Claiborne, Eoc	Smackover, Jur	McAlester Fuel Co.	95	1.3		11/64	1,700	Discovery well Spottsville Field
11	Columbia	33	16 S	19 W	7,403	Claiborne, Eoc	Smackover, Jur	McAlester Fuel Co.		.75	25	10/64	2,250	Discovery well Warnock Springs Ext.
12	Columbia	10	16 S	19 W	4,005	Claiborne, Eoc	Hosston, L. Cre	Morris, Kilpatrick, Calhoun & Petersen						D & A 8-23-49
13	Columbia	3	16 S	20 W	4,068	Claiborne, Eoc	Hosston, L. Cre	C. E. Murdock, Et Helms, R.H.Crow, Tr						D & A 8-30-49
14	Conway	9	6 N	17 W	1,720	Alluvium, Recent	Atoka, Pen.	C. L. Ohlinger						D & A 12-10-49
15	Crawford	30	10 N	31 W	1,873	Hartshorne, Pen	Atoka, Pen	Sher Developments, Ltd		2		Open flow	460	Discovery well Rudy Field
16	Crittenden	20	7 N	9 E	1,368	Alluvium, Recent	Wilcox, Eoc	Arnold Fowler, V. F. Brakensieck & G.A.Looney						D & A 12-20-49
17	Dallas	26	10 S	16 W	1,800	Claiborne, Eoc	Ozan, U. Cre	Jack Voyles et al						D & A 12-3-49
18	Drew	25	11 S	8 W	4,280	Jackson, Eoc	Igneous	Pet. Investment, Inc & Sneed Bros						D & A 5-27-49
19	Drew	23	13 S	6 W	4,193	Quaternary	Paleozoic	Sneed Bros						D & A 8-2-49
20	Franklin	27	9 N	28 W	6,650	Hartshorne, Pen	Everton, Ordov	Ark. Louisiana Gas Co		7		Open flow	1,224	Discovery well Cecil Field
21	Hempstead	3	11 S	24 W	2,111	Nacatoch, U. Cre	Eagle Mills, Jur	C. M. Bagley						D & A 12-27-49
22	Hempstead	28	10 S	25 W	2,511	Ozan, U. Cre	Paleozoic	J. H. Buchanan						D & A 12-31-49
23	Hempstead	32	10 S	24 W	2,204	Nacatoch, U. Cre	Eagle Mills, Jur	Aaron Freedman						D & A 5-25-49
24	Hempstead	35	10 S	24 W	1,833	Nacatoch, U. Cre	Eagle Mills, Jur	Sam Sklar, Tr						D & A 11-2-49
25	Jackson	34	9 N	1 W	1,970	Quaternary	Paleozoic	G. M. LeGrand						D & A 12-22-49
26	Lafayette	15	16 S	23 W	2,555	Claiborne, Eoc	Tokio, U Cre	Caddo Oil Co., Inc.						D & A 7-13-49
27	Lafayette	11	15 S	25 W	6,708	Alluvium, Recent	Smackover, Jur	McAlester Fuel Co						D & A 12-31-49
28	Lafayette	33	15 S	23 W	7,430	Claiborne, Eoc	Smackover, Jur	McAlester Fuel Co						D & A 1-18-49
29	Lafayette	16	16 S	23 W	4,015	Claiborne, Eoc	Mooringsport, L Cre	E. L. Pinkston						D & A 12-23-49
30	Lafayette	15	15 S	23 W	6,791	Wilcox, Eoc	Smackover, Jur	E. L. Pinkston						D & A 9-1-49
31	Lafayette	22	16 S	23 W	5,007	Claiborne, Eoc	Hosston, L. Cre	G. H. Vaughn						D & A 1-13-49
32	Lawrence	27	15 N	1 W	501	Quaternary	Paleozoic	C. H. Larson						D & A 6-16-49
33	Lee	33	3 N	1 E	200	Quaternary	Claiborne, Eoc	George Magan						Temp. Aba 7-1-49
34	Little River	35	12 S	31 W	3,678	Quaternary	Paleozoic	R. W. Burnett						D & A 11-2-49
35	Little River	35	12 S	31 W	3,547	Quaternary	Cotton Valley, Jur	R. W. Burnett						D & A 9-25-49
36	Little River	5	13 S	31 W	3,600	Quaternary	Paleozoic	R. W. Burnett						D & A 10-16-49
37	Little River	35	12 S	31 W	3,683	Quaternary	Paleozoic	Lee & Burnett						D & A 2-11-49
38	Little River	35	12 S	31 W	3,483	Quaternary	Cotton Valley, Jur	Lee & Burnett						D & A 3-27-49
39	Little River	32	12 S	30 W	3,515	Quaternary	Cotton Valley, Jur	McAlester Fuel Co						D & A 4-24-49
40	Madison	25	15 N	27 W	765	Atoka, Pen	Fayetteville, Mis	J. V. McCallister, Tr						D & A 6-16-49
41	Madison	30	15 N	27 W	710	Atoka, Pen	Fayetteville, Mis	J. V. McCallister, Tr						D & A 5-1-49
42	Madison	15	15 N	27 W	760	Atoka, Pen	Fayetteville, Mis	J. V. McCallister, Tr						D & A 5-1-49
43	Madison	28	15 N	27 W	805	Hlovd, Pen	Batkin, Mis	J. V. McCallister, Tr						D & A 4-20-49
44	Miller	18	16 S	25 W	5,087	Alluvium, Recent	Hodessa, L Cre	Garland Anthony						D & A 11-14-49
45	Miller	8	17 S	26 W	4,008	Quaternary	Paluxy, L Cre	H. Barksdale Brown & Co						D & A 8-15-49
46	Miller	33	14 S	27 W	6,228	Alluvium, Recent	Smackover, Jur	Plains Prod. Co						D & A 9-8-49
47	Miller	31	14 S	27 W	3,415	Alluvium, Recent	Hodessa, L Cre	B. P. Seay						D & A 12-31-49
48	Miller	8	17 S	28 W	1,606	Quaternary	Nacatoch, U Cre	Herman C Taylor						D & A 10-3-49
49	Miller	24	15 S	26 W	4,643	Quaternary	Sligo, L Cre	J. K. Wadley						D & A 11-14-49
50	Monroe	26	2 N	3 W	3,019	Alluvium, Recent	Paleozoic	Stratton Drlg. Co. Inc						D & A 4-8-49
51	Nevada	26	14 S	22 W	3,512	Alluvium, Recent	Hodessa, L Cre	H.Barksdale Brown & Co						D & A 8-7-49
52	Nevada	8	11 S	21 W	1,942	Quaternary	Smackover, Jur	James Marvin Campbell						D & A 3-23-49
53	Nevada	10	12 S	21 W	2,926	Wilcox, Eoc	Eagle Mills, Jur	Carter Oil Co						D & A 1-18-49

TABLE 2 - Continued SUMMARY OF DRILLING OPERATIONS IN ARKANSAS

IMPORTANT WILDCATS DRILLED IN 1949

LINE NUMBER	COUNTY OR LOCALITY	LOCATION SEC. SURVEY	LOCATION TWP. LAT.	LOCATION RGE. LONG.	TOTAL DEPTH, FT. OR METERS	FORMATION	DEEPEST HORIZON TESTED	DRILLED BY	INITIAL PRODUCTION PER DAY OIL, U.S. BBL.	INITIAL PRODUCTION PER DAY GAS, MILLIONS CU. FT.	INITIAL PRODUCTION PER DAY CONDENSATE (LIQ. BBL.	CHOKE, FRACTIONS OF AN INCH	TUBING PRESSURE, LB. PER SQ. IN.	REMARKS
54	Nevada	35	13 S	23 W	5,200	Wilcox, Eoc	Smackover, Jur	N. A. Hardin, et al						D & A 1-15-49
55	Nevada	15	12 S	22 W	3,615	Midway, Eoc	Eagle Mills, Jur	McAlester Fuel Co						D & A 1-1-49
56	Nevada	1	15 S	21 W	4,004	Claiborne, Eoc	Hosston, L Cre	Pan-Am Southern Corp & E. L. Pinkston						D & A 12-10-49
57	Nevada	11	12 S	23 W	1,598	Quaternary	Rodessa, L Cre	J. K. Wadley						D & A 1-2-49
58	Nevada	3	10 S	23 W	827	Quaternary	Eagle Mills, Jur	C. L. Wickcliffe						D & A 3-2-49
59	Quachita	35	15 S	18 W	3,520	Quaternary	Hosston, L Cre	C. M. Bagley						D & A 8-3-49
60	Quachita	22	13 S	16 W	3,170	Alluvium, Recent	Eagle Mills, Jur	Brosco Corp						D & A 5-18-49
61	Quachita	28	14 S	18 W	5,400	Claiborne	Smackover, Jur	Carter Oil Co						D & A 2-8-49
62	Quachita	30	11 S	19 W	2,486	Alluvium, Recent	Eagle Mills, Jur	Carter Oil Co						D & A 2-20-49
63	Quachita	31	11 S	19 W	2,681	Wilcox, Eoc	Eagle Mills, Jur	Carter Oil Co						D & A 2-2-49
64	Quachita	8	15 S	17 W	4,035	Wilcox, Eoc	Cotton Valley, Jur	C. G. Davis						D & A 8-20-49
65	Quachita	17	15 S	18 W	3,772	Claiborne, Eoc	Hosston, L Cre	McAlester Fuel Co						D & A 7-17-49
66	Quachita	35	13 S	18 W	1,436	Claiborne, Eoc	Nacatoch, U Cre	C. E. Miller						D & A 11-18-49
67	Quachita	32	14 S	19 W	3,667	Claiborne, Eoc	Hosston, L Cre	H. T. Pannell, et al						D & A 9-29-49
68	Quachita	16	14 S	19 W	1,292	Claiborne, Eoc	Nacatoch, U Cre	Petersen Drlg Co						D & A 6-16-39
69	Quachita	30	15 S	18 W	4,020	Claiborne, Eoc	Hosston, L. Cre	Sample & Mather						D & A 8-8-49
70	Quachita	29	13 S	19 W	1,218	Claiborne, Eoc	Nacatoch, U Cre	A. J. Slagter, Jr.						D & A 4-24-49
71	Quachita	36	13 S	18 W	1,503	Claiborne, Eoc	Saratoga, U Cre	C. L. Waggoner						D & A 5-14-49
72	Pike	31	8 S	23 W	180	Brownstown, U Cre	Tokio, U Cre	House & Moore						Temp. Aba. 6-9-49
73	St. Francis	20	4 N	1 W	2,754	Quaternary	Paleozoic	Garson-Sands						D & A 9-2-49
74	Union	28	19 S	13 W	2,306	Claiborne, Eoc	Nacatoch, U Cre	C. M. Bagley						D & A 2-12-49
75	Union	36	19 S	13 W	2,423	Claiborne, Eoc	Nacatoch, U Cre	C. M. Bagley						D & A 2-28-49
76	Union	21	19 S	13 W	3,506	Claiborne, Eoc	Hosston, L Cre	C. M. Bagley						D & A 6-26-49
77	Union	17	19 S	13 W	3,514	Claiborne, Eoc	Hosston, L Cre	H.Barksdale Brown & Co						D & A 7-16-49
78	Union	16	19 S	13 W	3,514	Claiborne, Eoc	Hosston, L Cre	H.Barksdale Brown & Co.						D & A 12-16-49
79	Union	33	17 S	16 W	8,375	Claiborne, Eoc	Eagle Mills, Jur	Carter Oil Co (Reworked by Carnes & Milam)						D & A 12-5-49
80	Union	2	18 S	14 W	4,010	Claiborne, Eoc	Hosston, L Cre	R.H.Crow, Tr & Dorset Co						D & A 7-22-49
81	Union	3	18 S	16 W	2,199	Claiborne, Eoc	Nacatoch, U Cre	El Dorado Drlg. Co						D & A 9-4-49
82	Union	8	16 S	14 W	5,187	Alluvium, Recent	Smackover, Jur	Victor P. Grage, etal						D & A 8-22-49
83	Union	4	16 S	14 W	5,107	Alluvium, Recent	Smackover, Jur	Victor P. Grage etal						D & A 9-25-49
84	Union	19	19 S	12 W	2,391	Claiborne, Eoc	Nacatoch, U Cre	T. L. James & Co. Inc						D & A 12-1-49
85	Union	19	18 S	12 W	6,747	Claiborne, Eoc	Smackover, Jur	Jones-O'Brien Inc						D & A 10-24-49
86	Union	3	16 S	18 W	3,626	Quaternary	Hosston, L Cre	Curtis A. Kinard						D & A 12-2-49
87	Union	34	18 S	18 W	8,517	Claiborne, Eoc	Smackover, Jur	Lion Oil Co						D & A 8-9-49
88	Union	22	16 S	14 W	5,681	Claiborne, Eoc	Smackover, Jur	Walter Lowe						D & A 8-20-49
89	Union	24	17 S	13 W	2,512	Claiborne, Eoc	Ozan, U Cre	Guy Mabee Drlg. Co						D & A 1-18-49
90	Union	35	18 S	15 W	8,010	Claiborne, Eoc	Smackover, Jur	MacMillan Pet. Corp. & Zach Brooks Drlg. Co.	144	.08		10/64	1,075	Discovery well Loutre Creek Field
91	Union	1	18 S	14 W	6,765	Claiborne, Eoc	Smackover, Jur	Marine Oil Co & Zach Brooks Drlg. Co.						D & A 11-6-49
92	Union	1	18 S	16 W	3,015	Claiborne, Eoc	Tokio, U Cre	Don D. Montgomery, etal						D & A 3-7-49
93	Union	25	17 S	18 W	7,611	Claiborne, Eoc	Smackover, Jur	Don D. Montgomery, etal						D & A 7-28-49
94	Union	6	19 S	14 W	2,193	Claiborne, Eoc	Nacatoch, U Cre	C. H. Murphy & Co						D & A 11-10-49
95	Union	10	16 S	17 W	6,241	Quaternary	Smackover, Jur	G. H. Vaughn & Sohio Pet. Co.						D & A 6-28-49

	IN PROVEN FIELDS	WILDCATS
Number of wells drilling Dec. 31, 1949	34	7
Number of wells completed during 1949	264	95
Number of gas wells completed during 1949	5	3
Number of dry holes completed during 1949	78	89

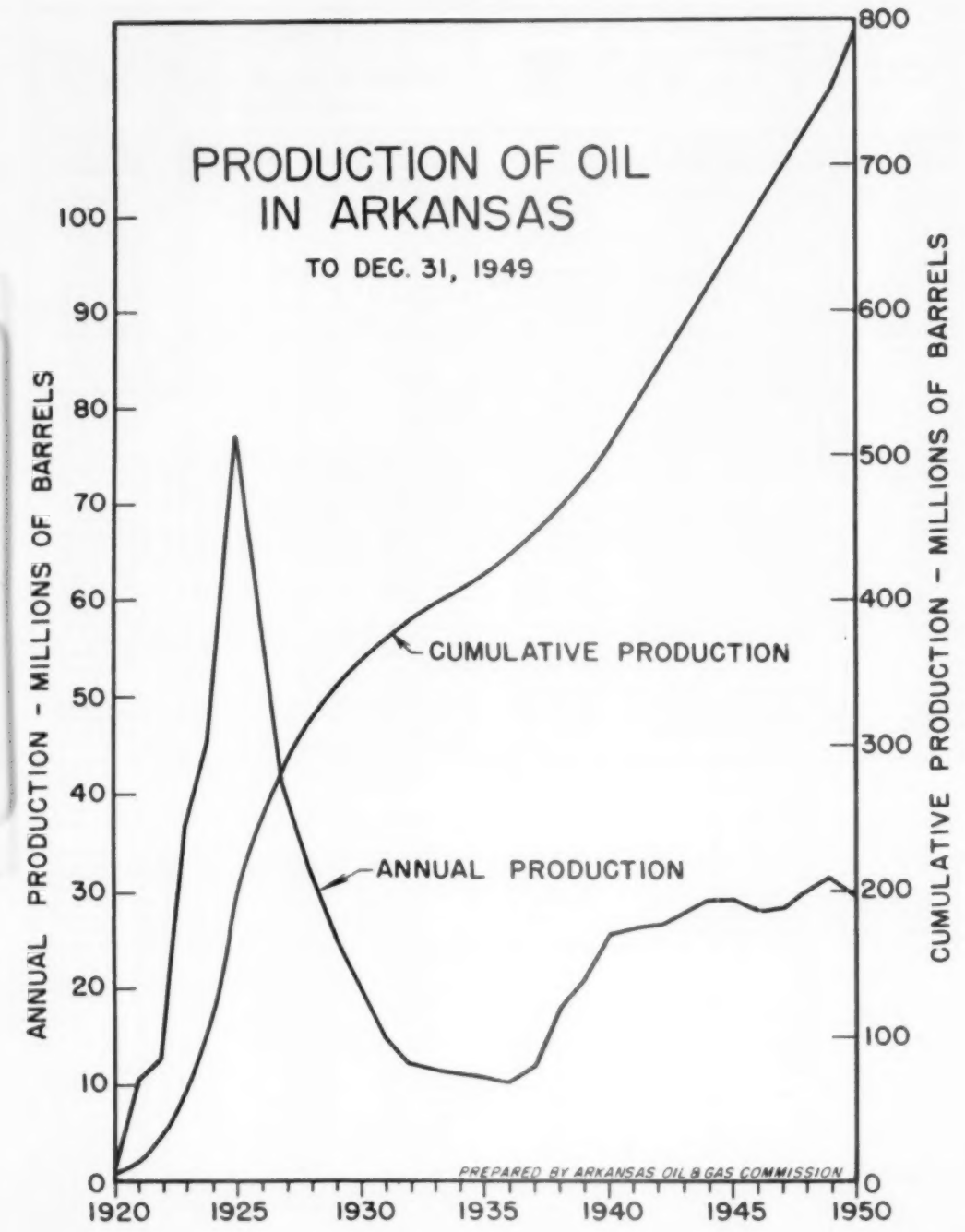

PRODUCTION OF OIL
IN ARKANSAS
TO DEC. 31, 1949
ANNUAL PRODUCTION - MILLIONS OF BARRELS
CUMULATIVE PRODUCTION - MILLIONS OF BARRELS
CUMULATIVE PRODUCTION
ANNUAL PRODUCTION
PREPARED BY ARKANSAS OIL & GAS COMMISSION
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
1920
1925
1930
1935
1940
1945
1950

FIG - 2

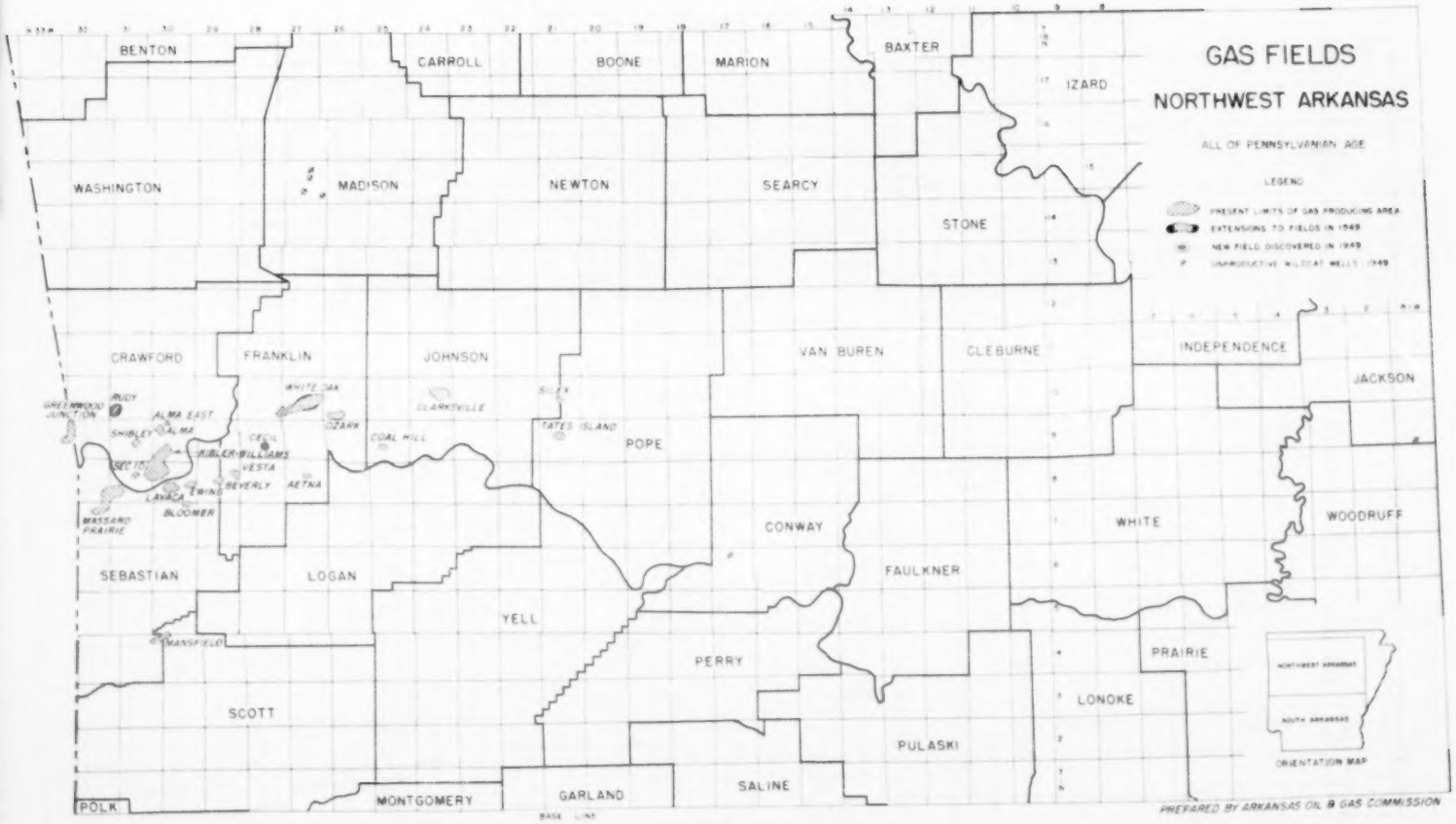
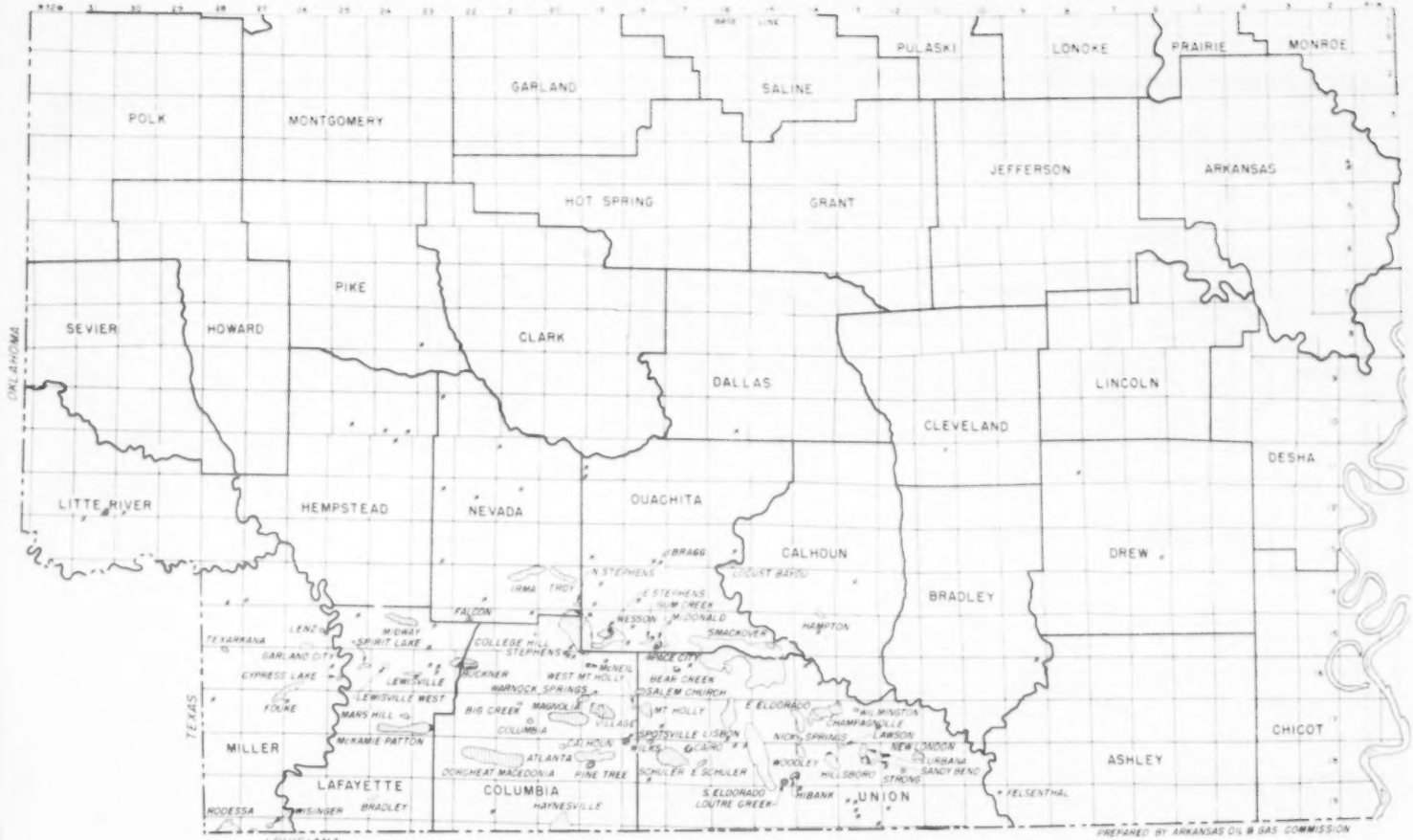


FIG - 3

DONALD K. MACKAY



OIL AND GAS-CONDENSATE FIELDS-SOUTH ARKANSAS

FIG - 4

Oil And Gas Developments In North Texas During 1949

By W. G. SINCLAIR, *Member AIME

The North Texas district presented in this paper includes the counties of Archer, Baylor, Clay, Cooke, Denton, Foard, Hardeman, Jack, Knox, Montague, Wichita, Wilbarger, Wise and Young. It corresponds with the Texas Railroad Commission's District 9 and includes Denton and Wise Counties transferred to the district during the year. Table 1 conforms with the nomenclature of the fields as designated by the Commission. Most of the oil and gas produced in this region, generally referred to as the Red River uplift, comes from the Pennsylvanian strata. In recent years, however, increasing amounts are being developed in both the Mississippian and Ordovician.

DEVELOPMENT DURING 1949

There were 2,715 wells drilled during 1949, an increase of 373 as compared with the previous year. Approximately 60 per cent of these tests or 1,521 were completed as oil wells with a combined initial production of 209,864 B/D, 15 as gas wells and 1,179 as dry holes. The location of the year's activity is shown in Table 3. A total of 128 new oil fields or extensions to the established areas of production were discovered. The combined initial production of these wells amounted to 25,467 B/D. Only a fraction of the new fields were given a name by the Nomenclature Committee of the Texas Railroad Commission. Table 5 gives the location, name and initial production of each of the new fields as designated by the Commission. All of the discoveries not allocated are shown in Table 1 under "All Other Fields" and in the county in which each is located.

ORDOVICIAN ACTIVITIES

A total of 71 wells tested the Ellenburger dolomite. Seventeen were completed as oil producers with a combined initial production of 4,114.27 B/D; nine were plugged back and completed as producers in shallow pays and 45 were dry. The location of these wells is shown by tabulation in Table 6.

REFINERY OPERATIONS

There are ten refineries in the area of which eight were operating at the close of the year. The location, capacity and daily thruput of these plants are shown in Table 7.

NATURAL GASOLINE PRODUCTION

The natural gasoline production in District 9 amounted to 2,685,800 bbl of 42 gal during the year. Continental Oil Co., Warren Oil Corp. and Phillips Petroleum Co. produced approximately 65 per cent of the year's total. See Table 8.

PRODUCTION

Production for the year amounted to 49,110,654 bbl of crude oil ranging from 19° to 50° but with an average of 40° gravity. Compared with 51,047,867 bbl in 1948, it is a decrease of 1,937,213 bbl. The cumulative production amounted to 1,095,128,194 bbl at the close of the year. There were 21,021 producing oil wells, of which number 1,056 were flowing and 19,965 were pumping.

MARKET PRICE

The posted price of 40° A P I gravity oil as of Jan. 1, 1949, remained unchanged at $2.65 per bbl.

GENERAL OUTLOOK FOR 1950

The demand for crude oil was somewhat abated at the end of 1949; however, drilling operations continued brisk into the new year due to the fact that the market price was still sufficient to pay the operator a fair return on his investment.

ACKNOWLEDGMENTS

The writer is indebted to Wm. M. Lourcey, head of the Land, Leasing and Scouting Department of the Gulf Oil Corp., Fort Worth, Texas, for permission to prepare this paper.

*Gulf Oil Corporation, Wichita Falls, Texas.

Manuscript received at the office of the Institute, June, 1950.

TABLE I OIL AND GAS PRODUCTION STATISTICS FOR NORTH TEXAS IN 1949

LINE NUMBER	FIELD (County)[a]	PRODUCING FORMATION NAME AND AGE[b]	YEAR OF DISCOVERY	OIL PRODUCTION			GAS PRODUCTION			GAS/OIL RATIO[d] MCF/BBL	CONDENSATE PRODUCTION Thousands of Bbl	
				AREA PROVED ACRES	BARRELS TO END OF 1949	BARRELS DURING 1949	AREA PROVED ACRES	MILLION CU. FT.[c] TO END OF 1949	MILLION CU. FT.[c] DURING 1949		TO END OF 1949	DURING 1949
	Archer											
1	Aberercrombie-Wilson	Strawn, Pen	1949	240	49,452	49,452						
2	Burns-Ickert	Bend, Pen	1943	80	86,530	2,225						
3	Burns-Jones	Strawn, Pen	1948	440	406,930	248,129						
4	Chalk Hill, North	Strawn, Pen	1947	1,960	1,406,534	716,380						
5	Cooper	Bend, Pen	1942	100	180,713	54						
6	Dixie	Strawn, Pen	1944	1,500	1,685,348	224,208						
7	Garrett	Strawn, Pen	1944	80	148,367	11,654						
8	Henry	Cisco, Pen	1943	240	49,211	4,275						
9	Holliday	Strawn, Pen	1944	200	382,561	30,448						
10	Holliday, East	Strawn, Pen	1946	(See Dixie)	2,082,222	553,494						
11	Hull-Salk-Sikes	Strawn, Pen	1939	7,500	37,306,896	3,261,357						
12	Hull-Salk-Sikes - Caddo	Strawn	1940	500	460,362	3,827						
13	Hunter Bros.	Mis, Mis	1948	80	67,741	56,538						
14	Kadane	Strawn, Pen	1940	740	2,110,096	331,839						
15	Kadane, Shallow	Cisco, Pen	1941	80	278,349	70,902						
16	King-Wilson	Strawn, Pen	1948	160	135,343	123,534						
17	Lipscomb	Strawn, Pen	1948	60	33,195	20,361						
18	Luke	Bend, Pen	1943	500	803,355	24,502						
19	Mankins	Bend, Pen	1939	500	1,280,940	67,493						
20	Neal	Mis, Mis	1948	80	59,445	44,622						
21	Ord	Bend, Pen	1944	120	32,305							
22	Reno Baptist	Strawn, Pen	1949	80	3,335	3,335						
23	Reno 3700' Strawn Sd	Strawn, Pen	1948	480	195,563	109,060						
24	Reno 3900' Strawn Sd	Strawn, Pen	1948	305	48,813	34,501						
25	Reno-Strawn, East	Strawn, Pen	1949	15	6,752	6,752						
26	Scotland Caddo	Bend, Pen	1940	280	777,245	6,419						
27	Scotland "M" Sd	Strawn, Pen	1946	160	137,215	40,960						
28	Scotland "N" Sd	Strawn, Pen	1945	120	107,782	35,085						
29	Scotland 4500' Sd	Strawn, Pen	1946	280	155,943	51,950						
30	Scotland Mis L	Mis, Mis	1941	160	325,335	5,214						
31	T. K. S.	Strawn, Pen	1949	10	12,266	12,266						
32	Vogtsberger	Strawn, Pen	1940	1,720	1,819,014	258,502						
33	Vogtsberger Strawn Sd	Strawn, Pen	1949	200	12,164	12,164						
34	West Archer City	Strawn, Pen	1949	80	6,259	6,259						
35	Other Fields	Cisco, Canyon, Pen	1911	44,700	145,865,245	3,702,892						
36	Total Archer County			62,850	198,538,098	10,210,703						
	Baylor											
37	Bentham	Canyon, Pen	1940	580	589,573	84,870						
38	Seymour	Canyon, Pen	1940	1,600	3,614,524	281,166						
39	Other Fields	Gunsite, Pen	1925	600	5,644,103	74,114						
40	Total Baylor County			2,780	9,847,200	441,150						
	Clay											
41	Acme	Strawn, Pen	1947	880	993,868	534,136						
42	Acme, Mis L	Mis, Mis	1948	200	139,708	62,450						
43	Antelope	Strawn, Pen Bend, Pen	1940	1,660	5,486,119	582,978						
44	Antelope, Mis L	Mis, Mis	1941	80	275,062	23,038						
45	Bryant Edwards	Bend, Pen	1946	400	697,796	109,602						
46	Bryant Simpson	Simpson, Ord	1947	240	387,966	102,779						
47	Burns-Hessning	Strawn, Pen	1939	320	271,374	13,694						
48	Burns-Midway	Mis, Mis	1943	120	383,377	46,227						
49	Grace	Bend, Pen	1948	180	72,118	60,157						
50	Halsell	Canyon, Pen Strawn, Pen	1939	500	1,184,463	76,189						
51	Haywood, Caddo	Bend, Pen	1940	120	429,723	17,686						
52	Haywood, Strawn	Strawn, Pen	1946	40	19,923	4,881						
53	Heard Ellenburger	Ellenburger, Ord	1945	40	176,962	33,403						
54	Johnson-Scaling	Ellenburger, Ord	1948	280	182,495	98,845						
55	Joy, Mis L	Mis, Mis	1941	520	1,240,764	66,795						
56	Joy Strawn	Strawn Penn	1943	3,520	4,442,967	1,369,798						
57	Kinder	Strawn, Pen	1939	40	16,464							
58	Lazy "B"	Bend, Pen	1949	440	120,224	120,224						
59	New York City Mis L	Mis, Mis	1949	360	819,033	1,935						
60	New York City Strawn	Strawn, Pen	1942	40	8,723							
61	Ross	Bend, Pen Ellenburger, Ord	1939	1,800	1,787,489	252,381						
62	Ross, West	Bend, Pen	1944	160	39,441							
63	Scaling	Bend, Pen	1944	120	183,383	32,951						
64	Stephens	Mis, Mis	1943	80	125,978	5,002						
65	Watson	Bend, Pen	1942	520	399,061	30,167						
66	Wynn, Mis L	Mis, Mis	1943	200	467,894							
67	Other Fields	Cisco, Can, Strawn, Mis	1902	10,200	17,945,465	805,832						
68	Total Clay County			23,360	38,076,814	4,441,340						
	Cooke County											
69	Atcheson	Ellenburger, Ord	1947	40	33,224	7,155						
70	Bandel	Strawn, Pen	1941	120	47,607	4,467						
71	Bandel, Ellenburger	Ellenburger, Ord	1941	120	274,904	12,823						
72	Bangle	Ellenburger, Ord	1943	320	750,724	111,847						
73	Fleitman	Strawn, Penn	1943	320	88,856	8,988						
74	Gatewood	Strawn, Penn	1944	1,320	1,759,433	342,690						
75	Grant-Mickesett	Strawn, Pen	1946	110	162,616	39,802						
76	Grant-Virginia	Strawn, Pen	1947	240	85,675	17,857						
77	Kimbell-Sans Shoreline Sd	Strawn, Pen	1949	40	4,324	4,324						
78	Lemaster	Strawn, Pen	1949	80	8,232	8,232						

LINE NUMBER	NUMBER OF WELLS[a]			WELLS PRODUCING[b] DEC. 1949			RESERVOIR PRESSURE LB. PER SQ. INCH		SECONDARY RECOVERY[c]	CHARACTER OF OIL[d]		PRODUCING FORMATION					DEEPEST ZONE TESTED[n] TO END OF 1949	
	COMPLETED TO END 1949	1949		OIL		GAS	INITIAL	AVG./END 1949		GRAVITY A.P.I.	SULPHUR PER CENT	CHARACTER[f]	POROSITY PER CENT[g]	DEPTH TO TOP OF PRODUCING ZONE FT.[h]	PROD. THICKNESS AVG. FT. NET	STRUCTURE[k]	NAME	DEPTH OF HOLE FT.
		COMPLETED	ABANDONED	FLOWING	ARTIFICIAL LIFT													
1	6	6		3	3					42		S	P	3,713	20	A	Bend	3,865
2	1				1					41		L	P	4,468	39	A	Miss	5,165
3	31	3		1	30					41		S		3,209	14	A	Ellenburger	6,117
4	80	12		12	68					42.5		S	P	3,857	46	A	Bend	4,413
5	1		1							43		L	P	4,910	30	A	Ellenburger	5,028
6	45				45					43		S	P	4,074	14	A	Bend	4,947
7	2		1		1					42		S	P	3,780	20	A	Ellenburger	5,685
8	11				11					36		S	P	900	5	A	Cisco	1,140
9	6				6					44		S	P	3,902	37	A	Bend	4,983
10	64	4		42	22					43		S L	P	4,074	20	A	Bend	4,953
11	431	3		8	423					44		C g	P	4,300	100	A	Ellenburger	5,880
12	3			0	3					44		L	P	4,550	153	A	Ellenburger	5,880
13	2	2		1	1					43		L	P	4,988	48	A	Miss	5,036
14	40	3		3	37					42		S	P	4,337	10	A	Ellenburger	5,001
15	20	8			20					37		S	P	1,572	8	A M	Ellenburger	5,001
16	8	8			8					41		S	P	3,752	28	A	Ellenburger	5,684
17	6				6					40		S	P	2,430	15	A	Bend	4,755
18	19		3	1	15					42		L	P	4,881	10	A	Ellenburger	5,623
19	14				14					44		L	P	4,660	30	A	Ellenburger	5,425
20	2	2		2						47		L	P	5,189	21	A	Ellenburger	5,560
21	8									42		L	P	5,130	12	A	Ellenburger	5,890
22	2	2			2					41		S	P	3,768	3	A	Strawn	4,015
23	32	28		7	25					40		S	P	3,682	35	A	Strawn	4,005
24	7	5		1	6					42		S	P	3,916	12	A	Strawn	4,055
25	1	1		1						42		S	P	3,895	55	A	Strawn	4,055
26	7			4	3					40		L	P	5,030	100	A	Ellenburger	5,850
27	8				8					43		S	P	3,566	132	A	Ellenburger	5,850
28	3	1			3					41		S	P	3,935	22	A	Ellenburger	5,850
29	7	1			7					41.7		S	P	4,542	21	A	Ellenburger	5,850
30	3				3					44		L	P	5,254	174	A	Ellenburger	5,850
31	1	1			1					38		S	P	2,673	10	A	Strawn	3,819
32	43	4		10	33					43		S	P	4,656	15	A	Granite	7,915
33	5	5			5					41.8		S	P	3,494	14	A	Granite	7,915
34	2	2		2						42		S	P	3,716	8	A	Strawn	3,823
35	3,262	345	149	55	3,207													
36	4,183	446	154	153	4,017													
37	27	8			27					38		L	P	3,025	4	A	Strawn	4,326
38	38		1		37					36		L	P	2,525	20	N	Ellenburger	5,598
39	103	6			103					38		S	P	1,440	20	M L	Ellenburger	5,755
40	168	14	1		167													
41	49	5			49					40		S	P	4,018	18	A	Miss	5,867
42	5			1	4					40		L	P	5,774	93	A	Miss	5,867
43	85	1		1	84					42		S	P	3,150	38	A M	Ellenburger	6,168
										40		L	P	3,550	20	A M	Ellenburger	6,168
44	2				2					41		L	P	5,670	90	x	Ellenburger	6,168
45	11			1	10					45		C g	P	6,071	17	A	Ellenburger	6,554
46	6			3	3					45.7		D	P	6,118	20	A	Ellenburger	6,449
47	3				3					44		S	P	4,430	20	A	Ellenburger	6,014
48	3				3					45		L	P	6,010	40	A	Ellenburger	6,298
49	7	4			7					42.6		L	P	5,420	50	A	Ellenburger	6,615
50	15	1			13					42		L	P	3,600	17	A	Ellenburger	6,048
										42		S	P	4,756	44	A	Ellenburger	6,048
51	3				3					47		C g	P	5,972	20	A	Ellenburger	6,538
52	1				1					42		S	P	4,975	27	A	Ellenburger	6,627
53	1			1						41		L	P	6,468	28	A	Ellenburger	6,606
54	7			1	6					45		L	P	5,798	40	A	Ellenburger	5,823
55	9				7					45		L	P	5,894	73	A	Ellenburger	6,255
56	176	41		11	165					40		S	P	3,950	32	A	Ellenburger	6,255
														4,400	30	A	Ellenburger	6,255
57	1									44		S	P	4,128	22	A	Ellenburger	5,527
58	11	11		9	2					42.1		L	P	5,575	125	A	Ellenburger	6,195
59	9			6	2					44		L	P	6,180	123	A	Ellenburger	6,837
60	1									46		S	P	4,911	29	A	Ellenburger	6,837
61	55	2		5	30					46		D	P	5,358	32	A	Ellenburger	6,145
										46		D	P	5,626	31	A	Ellenburger	6,145
62	4									42		L	P	5,345	61	A	Ellenburger	5,680
63	3			1	2					41		L	P	5,554	16	A	Ellenburger	6,360
64	2				2					46		L	P	6,001	28	A	Ellenburger	6,720
65	13			1	3					41-43		S-L	P	3640-5452	22-30	A	Ellenburger	6,051
66	2									46		L	P	6,153	130	A	Ellenburger	6,814
67	770	96		7	673					42		S	P	x	x	A	Ellenburger	6,837
68	1,254	161		46	1,094													
69	1				1					40.2		D	P	1,936	46	A	Ellenburger	2,064
70	3				3					39		S	P	1,885	10	A	Ellenburger	3,784
71	4	2			2					36		D	P	3,242	9	A	Ellenburger	3,784
72	18	1		1	6					37		D	P	2,179	8	A	Granite	2,520
73	15	1			13					40		S	P	1,133	7	A	Ellenburger	1,703
74		137	3		127					35		S	P	1,578	7	A	Ellenburger	2,083
75		28	1		12					37		S	P	1,820	10	A	Ellenburger	2,701
76	15	3	1		14					41.8		S	P	2,237	8	A	Strawn	2,246
77	1	1			1					47		S	P	3,603	9	A	Ellenburger	6,365
78	2	2			2					43		S	P	2,748	7	A	Ellenburger	5,574

TABLE I CONTINUED OIL AND GAS PRODUCTION STATISTICS FOR NORTH TEXAS

LINE NUMBER	FIELD (County)[a]	PRODUCING FORMATION NAME AND AGE[b]	YEAR OF DISCOVERY	OIL PRODUCTION AREA PROVED ACRES	OIL PRODUCTION BARRELS TO END OF 1949	OIL PRODUCTION BARRELS DURING 1949	GAS PRODUCTION AREA PROVED ACRES	GAS PRODUCTION MILLION CU. FT.[c] TO END OF 1949	GAS PRODUCTION MILLION CU. FT.[c] DURING 1949	GAS/OIL RATIO[d] MCF/BBL	CONDENSATE PRODUCTION Thousands of Bbl. TO END OF 1949	CONDENSATE PRODUCTION Thousands of Bbl. DURING 1949
79	Savells Bend	Strawn, Pen	1944	2,440	5,189,999	1,261,309						
80	Savells Bend, Ellenburger	Ellenburger, Ord	1946	40	5,003							
81	Voth	Ellenburger, Ord	1939	790	1,128,998	59,767						
82	Walnut Bend	Upper Strawn, Pen	1938	2,180	14,739,177	1,263,399						
83	Walnut Bend, Atkins	Strawn, Pen	1947	140	313,943	96,371						
84	Walnut Bend, Bruhlmeyer	Strawn, Pen	1948	40	100,987	99,682						
85	Walnut Bend, Cox	Strawn, Pen	1947	210	626,428	271,296						
86	Walnut Bend, Ellenburger	Ellenburger, Ord	1947	240	218,341	87,100						
87	Walnut Bend, 2600' Sd	Strawn, Pen	1948	20	35,538	20,329						
88	Walnut Bend, Hudspeth	Strawn, Pen	1940	560	966,239	396,358						
89	Walnut Bend, Montgomery	Strawn, Pen	1944	240	305,090	7,569						
90	Walnut Bend, Winger	Lower Strawn, Pen	1943	1,600	5,668,786	681,644						
91	Wilson	Strawn, Pen	1944	1,030	1,467,298	341,088						
92	Wilson, 3300-4000' Sd	Strawn, Pen	1945	780	1,063,707	290,114						
93	Woodbine	Strawn, Pen	1944	1,120	1,888,781	445,660						
94	Other Fields	Cisco, Canyon, Pen	1924	5,720	30,259,490	1,306,772						
95	Total Cooke County			20,140	67,083,390	7,186,850						
	Denton County											
96	Bolivar	Strawn, Pen	1937	300	126,131	51,177						
97	Bolivar, North	Strawn, Pen	1948	130	56,647	56,647						
98	Bolivar, South	Strawn, Pen	1949	60	15,705	15,705						
99	Other Fields											
100	Total Denton County			490	198,483	123,529						
	Foard County											
101	Johnson	Canyon, Pen	1933	380	1,904,367	16,672						
102	Other Fields	Cisco, Strawn, Pen	1929	300	421,063	7,075						
103	Total Foard County			680	2,325,430	23,747						
	Hardeman County											
104	Chillicothe	Strawn, Pen	1944	40	2,021							
105	Other Fields											
	Total Hardeman County			40	2,021							
	Jack County											
106	Bardwell	Marble Falls, Pen	1939	80	54,520	2,054						
107	Bryson, North	Strawn, Pen	1947	40	1,469	593						
108	Bryson, Mis Line	Mis, Mis	1947	280	298,922	29,971						
109	Bryson, East	Strawn, Pen	1938	1,460	6,245,556	221,271						
110	Campsey, Ellenburger	Ellenburger	1949	160	58,586	58,586						
111	Campsey, Ellenburger, East	Ellenburger	1949	80	35,237	35,237						
112	Ellis	Bend, Pen	1943	930	1,264,738	100,574						
113	Ellis, Gunsite	Cisco, Pen	1945	340	274,857	46,506						
114	Ellis, Strawn	Strawn, Pen	1944	80	153,850	8,632						
115	Gresham, Ellenburger	Ellenburger	1949	40	4,761	4,761						
116	Hanlon, Caddo	Bend, Pen	1948	200	41,433	41,433						
117	Hanlon, Strawn	Strawn, Pen	1944	400	340,087	86,406						
118	Hoefle	Bend, Pen	1941	1,280	1,461,905	196,388						
119	Lester	Mis, Mis	1944	200	355,401	25,559						
120	Lester, Conglomerate	Bend, Pen	1948	80	20,316	5,929						
121	Matlock	Mis, Mis	1944	320	295,277	27,466						
122	McDonald, Strawn	Strawn, Pen	1938	440	1,083,483	179,200						
123	Meyers	Strawn, Pen	1938	120	171,251	13,671						
124	Peek	Bend, Pen	1943	160	359,009	34,704						
125	Post Oak	Strawn, Pen	1949	40	9,821	9,821						
126	Post Oak, Ellenburger	Ellenburger	1949	200	82,948	82,948						
127	Rheney	Bend	1949	40	2,298	2,298						
128	Risch	Bend, Pen	1944	520	596,202	96,708						
129	Steed	Bend, Pen	1945	640	1,086,651	105,611						
		Strawn, Pen	1941									
130	Taubert-McKee	Ellenburger, Ord	1942	40	6,824							
131	Tilghman-Mis. Line	Mis, Mis	1949	40	5,709	5,709						
132	Webb	Strawn, Pen	1941	40	3,883							
133	Weir	Strawn, Pen	1943	100	130,107	17,827						
134	Wolfe	Bend, Pen	1943	280	140,727	61,804						
135	Worsham, Steed	Strawn, Pen	1942	2,195	488,255	290,913						
136	Other Fields		1913	6,560	21,164,601	558,195						
137	Total Jack County			17,385	36,173,704	2,353,295						
	Knox County											
138	Other Fields	Bend, Pen	1946	40	1,251							
139	Total Knox County			40	1,251							
	Montague County											
140	Barrett	Bend, Pen	1948	40	19,190	11,472						
141	Belcherville	Bend, Pen	1945	440	683,798	132,302						
142	Benson	Bend, Pen	1941	120	115,130	9,212						
143	Bonita	Strawn, Pen	1940	380	1,738,968	67,766						
144	Bowers	Canyon, Pen	1939	1,060	3,037,240	262,508						
145	Bowers, South	Strawn, Pen	1947	140	364,075	101,656						
146	Caudle	Bend, Pen	1946	80	212,511	40,784						
147	Chapman-McFarlin	Strawn, Pen	1941	280	762,357	146,050						
148	Clingingsmith	Bend, Pen	1941	240	292,973	9,184						

LINE NUMBER	NUMBER OF WELLS[a]			WELLS PRODUCING[f] DEC. 1949			RESERVOIR PRESSURE LB PER SQ INCH		SECONDARY RECOVERY[g]	CHARACTER OF OIL[b]		PRODUCING FORMATION					DEEPEST ZONE TESTED[c] TO END OF 1949	
	COMPLETED TO END 1949	1949		OIL		GAS	INITIAL	AVG./END 1949		GRAVITY A.P.I.	SULPHUR PER CENT	CHARACTER[i]	POROSITY PER CENT[j]	DEPTH TO TOP OF PRODUCING ZONE FT	PROD. THICKNESS AVG. FT / NET	STRUCTURE[k]	NAME	DEPTH OF HOLE, FT
		COMPLETED	ABANDONED	FLOWING	ARTIFICIAL LIFT													
79	64				61					36		S	P	6,761	16	A	Ellenburger	9,550
80	1									41.7		D	P	8,905	35	A	Ellenburger	9,550
81	76		1		67					38		L	P	1,625	10	A	Ellenburger	1,793
82	180	21			141					39		S	P	4,108	7	N	Ellenburger	6,880
83	7				7					43.2		S	P	5,229	51	x	Ellenburger	6,880
84	4	4		3	1					40		S	P	3,450	30		Ellenburger	6,880
85	21		1	16	14					40.8		S	P	2,903	11	x	Ellenburger	6,880
86	6	1			6					35		D	P	5,241	110	A	Ellenburger	6,880
87	1				1					43		S	P	2,640	26	A	Ellenburger	6,880
88	28	7		18	10					39.4		S	P	4,068	12	A	Ellenburger	6,880
89	6		1		2					45		S	P	5,112	19	x	Ellenburger	6,330
90	45	1			45					33.5		S	P	5,491	42	N	Ellenburger	6,110
91	103	4			103					41.7		S	P	2,221	10	A M	Ellenburger	4,302
92	39	1			39					31		S	P	3,933	10	A	Ellenburger	4,302
93	56	1	1		54					29		S	P	4,118	18	x	Ellenburger	4,867
														4,349	8	x		
														4,512	10	x		
94	1,144	64	10	2	1,089					40		S L	P	x	x	x	Ellenburger	9,550
95	2,005	114	19	40	1,820													
96	30	30		6	24					38		S	P	1,500	20	A	Bend	2,520
97	13	13		6	7					33		S	P	1,740	15	A	Bend	2,520
98	6	6			6					35.2		S	P	1,531	6	A	Bend	2,520
99																		
100	49	49		12	37													
101	13			1	6					50		L	P	3,565	42	A	Pre-Cambrian	5,003
102	13				5					49		S	P	2,050	14		Ellenburger	5,830
												L		4,822	20	A		
103	26			1	11													
104	1									44		L	P	4,250	27	x	Miss	7,301
105	1																	
106	2				2					41		L	P	4,384	20	A	Miss	4,507
107	1			1	0					40		S	P	3,269	19	A	Strawn	4,522
108	7	2		4	3					45.3		L	P	5,097	34	A	Miss	5,154
109	146		2	6	112					42		S	P	3,110	10	A	Ellenburger	5,485
110	4	4			4					45.2		L	P	6,333	24	A	Ellenburger	6,501
111	2	2		1	1					45.1		L	P	6,225	117	A	Ellenburger	6,501
112	30		3	12	14					43		L	P	4,785	43	A	Ellenburger	6,153
113	34				34					41		S	P	550	31	A	Ellenburger	6,153
114	2				2					42		S	P	3,629	8	A	Ellenburger	6,153
115	1	1			1					44		L	P	5,695	85	A	Ellenburger	6,051
116	5	5		4	1					45		L	P	4,564	26	A	Ellenburger	6,153
117	20		4		16					42		S	P	3,606	5	A	Ellenburger	6,153
118	32	5		13	17					43		S	P	2,712	10	A	Ellenburger	6,177
												L	P	4,794	41			
119	5		1	3						47.2		L	P	5,458	54	A	Ellenburger	5,512
120	2	1		1	1					44		C g	P	4,975	17	A	Ellenburger	5,512
121	8		2	3	3					47		L	P	5,311	33	A	Ellenburger	5,344
122	22	1			21					33.6		S	P	3,518	20	A	Ellenburger	6,040
123	9	1			7					40		S	P	2,401	10	A	Ellenburger	6,215
124	8			2	6					40		L	P	4,579	10	A	Bend	4,589
125	1	1			1					41		S	P	3,792	3	A	Ellenburger	6,501
126	5	5			5					45		L	P	6,240	18	A	Ellenburger	6,501
127	1	1			1					42		L	P	4,570	15	A	Bend	5,058
128	13			3	10					40		L	P	4,381	42	A	Ellenburger	6,407
129	32		1	25	6					42		L	P	4,770	30	A	Miss	5,344
										40		S		3,246	60			
130	1									42		D	P	6,388	47	A	Ellenburger	6,501
131	1	1		1						44		L	P	5,390	18	A	Miss	5,408
132	1									42		S	P	2,892	16	A	Ellenburger	6,175
133	5				5					41		S	P	2,322	10	A	Ellenburger	6,011
134	14	11		12	2					40		L	P	4,366	60	A	Ellenburger	5,631
135	59	56		40	19					41		L	P	4,696	20	A	Bend	5,252
136	769	53	16	29	474					38		x	x	x	x	x	Ellenburger	7,048
137	1,242	150	29	160	767													
138	1									48		L	P	6,225	22	A	Ellenburger	6,785
139	1																	
140	1				1					40		C g	P	6,410	16	A	Miss	6,570
141	11	1		6	5					44		C g	P	5,347	13	A	Ellenburger	5,913
142	3				3					44		C g	P	5,840	10	A	Ellenburger	6,213
143	15		1		12					40		S	P	5,442	14	A	Ellenburger	6,975
												S		5,234	10			
144	53	2			49					40		S	P	2,880	15	A	Granite	4,300
												L		2,020	10			
145	7	1		1	6					39.6		S	P	4,047	47	A	Strawn	4,168
146	2			2						45.6		C g	P	6,131	43	A	Bend	6,243
147	14			9	5					42		L	P	5,996	22	A	Ellenburger	7,224
										44.7		S		4,826	36		Ellenburger	
148	6		1		1					40		C g	P	5,906	66	A	Bend	6,250

TABLE I CONTINUED OIL AND GAS PRODUCTION STATISTICS FOR NORTH TEXAS

LINE NUMBER	FIELD (County)[a]	PRODUCING FORMATION NAME AND AGE[b]	YEAR OF DISCOVERY	OIL PRODUCTION			GAS PRODUCTION			GAS/OIL RATIO[d] MCF/BBL	CONDENSATE PRODUCTION Thousands of Bbl	
				AREA PROVED ACRES	BARRELS TO END OF 1949	BARRELS DURING 1949	AREA PROVED ACRES	MILLION[c] CU FT TO END OF 1949	MILLION[c] CU FT DURING 1949		TO END OF 1949	DURING 1949
149	Dubon	Bend, Pen	1940	68	2,383,849	193,946						
150	Forestburg	Bend, Pen	1942	280	327,108	8,314						
151	Gronon, Strawn	Strawn, Pen	1948	160	33,189	18,248						
152	Hass	Bend, Pen	1949	40	10,961	10,961						
153	Hildreth	Bend, Pen	1942	7,000	12,321,951	1,279,301						
154	Hulta & Queens	Bend, Pen	1940	160	97,108							
155	Huntley	Bend, Pen	1944	560	851,990	195,907						
156	Illinois, Bend	Strawn, Pen	1942	300	427,635	31,284						
157	Kennedy, Caddo	Bend, Pen	1948	200	123,532	98,862						
158	Lewis-Stewart	Bend, Pen	1946		224,195							
159	Lewis-Stewart, Caddo	Bend, Pen	1947	1,120	940,191	482,669						
160	Magree	Strawn, Pen	1947	80	76,862	26,002						
161	Maguire	Bend, Pen	1948	160	87,027	81,574						
162	Miller, Conglomerate	Bend, Pen	1948	200	160,656	74,675						
163	Minor, Conglomerate	Bend, Pen	1948	160	194,576	120,028						
164	Minor, West	Bend, Pen	1949	120	47,040	47,040						
165	Mueller	Simpson, Ord	1942	120	197,865	32,966						
166	Mueller, Caddo	Bend, Pen	1943	280	768,898	73,733						
167	Queens Peak	Bend, Pen	1947	280	238,901	134,929						
168	Ringgold (Montague & Clay Counties)[f]	Strawn, Ben, Pen	1940	2,080	3,783,311	571,102						
169	Richardson, Caddo	Bend, Pen	1948	200	97,852	97,852						
170	Rogers & Rogers	Strawn, Pen	1938	1,100	3,378,269	164,537						
171	Sanders	Bend, Pen	1942	200	460,678	24,093						
172	Staley-Conglomerate	Bend, Pen	1948	40	38,416	36,148						
173	Stoneburg	Bend, Pen	1941	160	196,669	11,898						
174	Turner	Bend, Pen	1941	40	26,800							
175	Other Fields		1918	8,445	45,031,997	1,710,856						
176	Total Montague County			26,845	79,754,089	6,362,889						
	Wichita County											
177	Airport	Strawn, Pen	1943	80	52,438	5,642						
178	Davidson	Ellenburger, Ord	1943	140	239,187	23,431						
179	Hanson	Canyon, Pen	1948	400	210,958	188,210						
180	Hassler, Simpson	Simpson, Ord	1948	80	8,016	5,344						
181	Jones-Payne, Conglomerate	Bend, Pen	1947	80	84,550	19,022						
182	Kempner	Strawn, Pen	1947	1,620	1,033,334	655,323						
183	K. M. A.	Strawn, Pen	1931	36,600	81,385,798	2,929,062						
184	K. M. A., Ellenburger	Ellenburger, Ord	1940	7,760	15,010,121	699,201						
185	Lake Wichita, Caddo	Bend, Pen	1948	40	14,253	6,185						
186	West	Strawn, Pen	1944	1,520	2,064,178	372,494						
187	Wood	Cisco, Pen	1948	240	24,259	17,880						
188	Other Fields	Cisco, Pen	1911	65,260	356,737,427	4,887,734						
189	Total Wichita County			113,820	456,864,459	9,809,548						
	Wilbarger County											
190	Baker	Cisco, Pen	1949	120	15,482	15,482						
191	Consolidated	Strawn, Pen	1939	700	1,865,956	67,692						
192	Electra, Ellenburger	Ellenburger, Ord	1941	40	57,881	4,651						
193	Fargo	Cisco, Canyon, Strawn, Pen	1940	2,520	7,118,360	610,841						
194	Fargo, Ellenburger	Ellenburger, Ord	1947	280	334,299	69,897						
195	Grayback, Ellenburger	Ellenburger, Ord	1949	40	11,620	11,620						
196	Harrold	Cisco, Canyon, Pen	1940	720	440,052	19,851						
197	King	Cisco, Canyon, Pen	1939	60	109,311	3,833						
198	Main	Canyon, Penn	1943	180	105,626	3,066						
199	National, Caddo	Bend, Pen	1946	140	205,877	20,141						
200	National, Canyon Lime	Canyon, Pen	1945	600	659,341	56,002						
201	National, Ellenburger	Ellenburger, Ord	1945	600	619,466	48,541						
202	National K. M. A. Lime	Strawn, Pen	1946	40	61,131							
203	National Victory	Canyon, Pen	1946	80	146,250	11,884						
204	O'Dell	Canyon, Pen	1944	280	364,348	27,127						
205	O'Dell, West	Canyon, Pen	1948	80	26,121	14,575						
206	O'Dell, Ellenburger	Ellenburger, Ord	1948	120	36,094	36,094						
207	Paradise Canyon Lime	Canyon, Pen	1946	100	53,171	12,623						
208	Potts, Ellenburger	Ellenburger, Ord	1942	80	58,560	4,730						
209	Rock Crossing Canyon Lime	Canyon, Pen	1942	600	1,834,312	116,652						
210	Rock Crossing, Ellenburger	Ellenburger, Ord	1941	280	592,711	33,671						
211	Rogers, McCrary	Cisco, Pen	1943	90	102,440	9,604						
212	Tolbert	Canyon, Pen	1946	80	55,724	11,274						
213	Other Fields	Cisco, Canyon, Strawn, Pen	1915	18,095	87,218,695	1,564,297						
214	Total Wilbarger County			25,855	102,142,828	2,774,168						
	Wise County											
215	Chico	Bend, Bend		200	143,537	62,569						
216	Chico, West	Bend, Pen	1948	2,040	1,174,446	898,157						
217	Daly, Caddo	Bend, Pen	1949	40	19,979	19,979						
218	Park Springs	Bend, Pen	1942	40	2,183							
219	Other Fields	Strawn, Pen	1948	80	4,749	3,782						
220	Total Wise County			2,360	1,344,894	984,487						

LINE NUMBER	NUMBER OF WELLS[a]			WELLS PRODUCING[f] DEC. 1949			RESERVOIR PRESSURE LB PER SQ INCH		SECONDARY RECOVERY[g]	CHARACTER OF OIL[h]		PRODUCING FORMATION					DEEPEST ZONE TESTED[m] TO END OF 1949	
	COMPLETED TO END 1949	1949		OIL		GAS	INITIAL	AVG. /END 1949		GRAVITY A.P.I.	SULPHUR PER CENT	CHARACTER[i]	POROSITY PER CENT[j]	DEPTH TO TOP OF PRODUCING ZONE FT[k]	PROD. THICKNESS AVG. FT / WT	STRUCTURE[l]	NAME	DEPTH OF HOLE, FT
		COMPLETED	ABANDONED	FLOWING	ARTIFICIAL LIFT													
149	34		3	1	25					43.2		L Ge	P	5,127	25	A	Ellenburger	6,368
														5,291	8			
150	7	2			5					40		L	P	7,176	53	A	Ellenburger	8,698
151	4	2			4					38		S	P	4,079	6	A	Bend	6,570
152										40.1		L	P	6,255	45	A	Bend	6,622
153	175		4	25	129					40		Ge	P	6,050	150	A	Ellenburger	7,413
154	4									43		L	P	6,002	48	A	Bend	6,303
155	14	6		10	4					42		Ge	P	6,228	7	A	Ellenburger	8,018
156	5				5					30		S	P	3,463	10	A	Ellenburger	4,880
														3,860	12			
157	5	3		4	1					42		L	P	6,180	85	A	Bend	6,660
158										41		Ge	P	6,348	8	A	Mis	6,568
159	28	5		20	8					41		Ge	P	6,215	12	A	Mis	6,568
160	2			1	1					40		Ge-S	P	6488-6018	23-20	A	Bend	6,640
161	4	4		3	1					43.9		Ge	P	5,352	6	A	Bend	5,750
162	5			1	4					43		Ge	P	6,190	14	A	Ellenburger	6,713
163	4	1		3	1					40		Ge	P	6,182	72	A	Bend	6,576
164	3	3		3						43		Ge	P	6,292	10	A	Bend	6,576
165	3	1			3					42		D	P	7,218	5	A	Ellenburger	7,462
166	7			3	4					40		L	P	6,015	40	A	Ellenburger	7,462
167	7	3		6	1					41		Ge	P	6,231	16	A	Bend	6,540
168	52	7		24	27							S	P	4,820	40	A	Ellenburger	6,203
												S L		4,645	9			
												Ge		5,695	20			
169	5	5		5						42		L	P	6,154	19	A	Ellenburger	6,570
170	55	1		1	40					43		S L	P	4,645	9	A	Ellenburger	6,988
												Ge-L		5,224	11			
171	5				5					36		Ge	P	5,975	50	A	Ellenburger	6,860
172	1	1			1					40		Ge	P	5,970	10	A	Bend	6,101
173	4			1	3					44.8		Ge	P	6,180	30	A	Simpson	7,224
174	1									41		Ge	P	6,222	19	A	Ellenburger	7,501
175	1,689	150	8	12	1,150					x		x	x	x	x	x	x	8,616
176	2,235	198	17	141	1,504													
177	3				3					44		S	P	4,415	50	x	Ellenburger	5,401
178	4				4					47		D	P	5,350	11	x	Ellenburger	5,364
179	20	14		10	10					44		S	P	2,950	6	A	Canyon	2,977
180	2				2					45		L	P	5,668	10		Simpson	6,008
181	2	1			2					42		D	P	5,182	18	A	Ellenburger	5,200
												Ge		5,112	14			
182	81	40		37	44					40		S	P	3,910	15	x	Ellenburger	4,738
183	1,627	6	7	170	1,146					42		S L	P	3,699	41	A c	Ellenburger	5,430
184	194		41	1	152					42		D	P	4,330	30	A c	Ellenburger	5,430
185	1				1					40		L	P	4,182	16	A	Mis	5,525
186	76	14			76					40		S	P	4,228	30	x	Ellenburger	5,687
187	6	4			6					41.2		S	P	2,165	9	x	Canyon	2,603
188	6,965	326	120	27	5,198					40		S L	P	x	x	x	Ellenburger	6,221
189	8,981	405	168	245	6,644													
190	3	3			3					36.5		S	P	2,372	11	A	Cisco	2,552
191	32				30					40		S	P	3,750	20	A	Ellenburger	4,450
192	1				1					43		D	P	3,627	8	A	Ellenburger	4,635
193	91		2		87					42		S	P	3,278	20	A	Ellenburger	6,717
												L		4,028	18			
												S		4,430	15			
194	7				7					41.9		D	P	6,248	97	A	Ellenburger	6,717
195	1	1			1					39		L	P	3,910	19	A	Ellenburger	3,929
196	18		1		10					40		S	P	2,095	10	A	Ellenburger	5,746
												S		3,160	12			
197	5				5					38		S	P	1,220	10	A	Strawn	2,671
												S		1,900	12			
198	6				4					38		L	P	2,786	10	x	Granite Wash	4,725
199	7		2		5					39		L	P	4,450	-56	A	Ellenburger	5,035
200	27		9		18					39		L	P	3,649	3	A	Ellenburger	5,035
201	15		1		12					41		D	P	4,905	21	A	Ellenburger	5,035
202	1									40		S	P	4,806	12	A	Ellenburger	5,035
203	4				4					39		L	P	3,510	20	A	Ellenburger	5,718
204	6		1		5					43		L	P	4,750	60	A	Strawn	4,956
205	2				2					44		L	P	4,744	31	A	Ellenburger	6,836
206	3	3		2	1					44		L	P	6,474	100	A	Ellenburger	6,836
207	5	1		2	3					38		L	P	3,156	18	A	Ellenburger	4,964
208	2				1					42		D	P	4,506	48	A	Ellenburger	4,557
209	29		3		25					39		L	P	3,015	17	A	Ellenburger	3,883
210	7				6					39		D	P	3,804	11	A	Ellenburger	3,883
211	9				9					41		S	P	1,476	11	N	Cisco	1,489
212	2	1			1					41.7		L	P	5,015	9	A	Ellenburger	5,612
213	1,706	27	35	5	1,300					40		S L	P	x	x	A	Ellenburger	6,612
214	1,989	35	55	9	1,541													
215	6	6		5	1					42		Ge	P	5,203	12	A	Ellenburger	7,052
216	51	27		51	2					41		Ge	P	5,312	51	A	Ellenburger	7,310
217	6	6		1	5					41		L	P	3,870	15	A	Marble Falls	5,462
218	1									38.8		Ge	P	5,790	25	A	Ellenburger	7,310
219	1				1					40		S	P	3,940	18	A	Strawn	4,083
220	65	39		57	9													

TABLE 1 CONTINUED OIL AND GAS PRODUCTION STATISTICS FOR NORTH TEXAS

LINE NUMBER	FIELD (County)[a]	PRODUCING FORMATION NAME AND AGE[b]	YEAR OF DISCOVERY	OIL PRODUCTION			GAS PRODUCTION			GAS/OIL RATIO[d] MCF/BBL	CONDENSATE PRODUCTION Thousands of Bbl	
				AREA PROVED ACRES	BARRELS TO END OF 1949	BARRELS DURING 1949	AREA PROVED ACRES	MILLION CU FT[c] TO END OF 1949	MILLION CU FT[c] DURING 1949		TO END OF 1949	DURING 1949
	Young County											
221	Allar	Strawn, Penn	1941	280	781,783	115,297						
222	Allar, Caddo	Bend, Penn	1943	80	69,864	5,517						
223	Allar, Warren, Caddo	Bend, Penn	1949	40	14,565	14,565						
224	Anzac-Graham	Bend, Penn	1938	160	210,323	15,429						
225	Blount	Strawn, Penn	1940	40	15,810							
226	Briar Creek	Miss, Miss	1941	280	261,304	5,843						
227	Burns-Larsmore	Miss, Miss	1941	40	157,127	9,501						
228	Burns, Bagland, Miss, Lime	Miss, Miss	1942	160	350,922	23,982						
229	Burns, Bagland, Strawn	Strawn, Penn	1944	120	118,123	9,117						
230	Crain-Kunkel	Miss, Miss	1945	80	246,400	45,245						
231	Davis	Miss, Miss	1946	60	107,869	11,094						
232	Dines	Bend, Penn	1942	120	42,990	32,763						
233	Dillard	Miss, Miss	1946	200	110,906	9,865						
234	Edmonds	Bend, Penn	1943	80	73,418	5,908						
235	Elkins, Strawn	Strawn, Penn	1947	60	32,564	18,815						
236	F. B. H. P.	Cisco Penn	1948	100	56,709	47,716						
237	Fish Creek	Bend, Penn	1942	80	19,000	4,396						
238	Fish Creek, Miss, Lime	Miss, Miss	1948	60	18,748	18,748						
239	Fish Creek, Shallow	Strawn, Penn	1948	60	21,750	7,787						
240	Furr & Allar	Miss, Miss	1948	120	53,786	53,786						
241	Garvey	Bend, Penn	1941	400	549,438	46,294						
242	Garvey-Strawn	Strawn, Penn	1948	160	205,972	158,438						
243	Holbert, Caddo	Bend, Penn	1942	180	327,835	107,489						
244	James	Bend, Penn	1928	2,040	3,240,201	63,201						
245	Jeffrey	Miss, Miss	1949	40	2,642	2,642						
246	Kendall, Caddo	Bend, Penn	1946	300	488,517	108,135						
247	Kendall, Bend, Conglomerate	Bend, Penn	1947	200	50,486	7,739						
248	Kendall, Miss, Lime	Miss, Miss	1947	80	66,688	18,831						
249	Kendall, Strawn	Strawn, Penn	1947	220	231,736	176,523						
250	Keelyn-Loving	Strawn, Ben, Penn	1940	140	132,796	18,302						
251	Knight	Bend, Penn	1938	700	983,942	5,274						
252	Knox	Strawn, Penn	1931	1,220	1,443,263	60,898						
253	Knox, Basal, Caddo	Bend, Penn	1947	80	219,799	52,554						
254	Knox, Caddo, North	Bend, Penn	1936	540	699,180	20,977						
255	Knox, Mis, Lime	Mis, Mis	1942	720	857,546	96,992						
256	Lupton, McLester	Bend, Penn	1936	1,100	1,479,479	69,401						
257	Lynn	Strawn, Penn	1948	70	63,791	54,737						
258	Murray	Mis, Mis	1942	440	1,163,924	111,374						
259	Murray, Caddo	Bend, Penn	1943	240	141,672	31,228						
260	Padgitt, Mis, Lime	Mis, Mis	1942	280	435,650	13,892						
261	Padgitt, West	Mis, Mis	1947	120	148,817	63,026						
262	Prideaux	Strawn, Penn	1945	100	129,102	17,942						
263	Sewell, Caddo	Bend, Penn	1939	430	1,226,880	21,307						
264	Sewell, Chappell, Lime	Mis, Mis	1944	80	159,352	8,276						
265	Sewell, Marble Falls	Marble Falls, Penn	1940	360	266,085	15,855						
266	Sewell, Strawn	Strawn, Penn	1939	120	157,545	13,054						
267	Sweeney, Conglomerate	Bend, Penn	1948	60	59,883	37,688						
268	Swink	Mis, Mis	1948	80	62,693	61,074						
269	Taylor	Bend, Penn	1941	80	43,733	2,691						
270	Turner & West	Bend, Penn	1949	40	30,670	30,670						
271	Walsh	Bend, Penn	1943	330	236,562	88,819						
272	Warren, Caddo	Bend, Penn	1948	80	47,444	27,498						
273	Warren, Strawn	Strawn	1948	80	59,656	58,686						
274	Williamson	Strawn, Penn Bend, Penn Mis, Mis	1941	360	307,833	27,528						
275	Other Fields		1917	31,670	84,310,860	2,192,499						
276	Total Young County			45,400	102,795,533	4,398,948						
	GRAND TOTAL			341,945	1,095,128,194	49,110,654						

LINE NUMBER	NUMBER OF WELLS[4]			WELLS PRODUCING[5] DEC. 1949			RESERVOIR PRESSURE LB PER SQ INCH		SECONDARY RECOVERY[6]	CHARACTER OF OIL[8]		PRODUCING FORMATION					DEEPEST ZONE TESTED[11] TO END OF 1949	
	COMPLETED TO END 1949	1949		OIL		GAS	INITIAL	AVG. END 1949		GRAVITY A.P.I.	SULPHUR PER CENT	CHARACTER[1]	POROSITY PER CENT[7]	DEPTH TO TOP OF PRODUCING ZONE FT	PROD. THICKNESS AVG. FT NET	STRUCTURE[9]	NAME	DEPTH OF HOLE, FT
		COMPLETED	ABANDONED	FLOWING	ARTIFICIAL LIFT													
221	14			1	11					38		S	P	2,706	15	A	Ellenburger	4,485
222	2				2					37		L	P	3,550	20	A	Ellenburger	4,485
223	1	1		1						41		L	P	3,568	5	A	Ellenburger	4,485
224	4				4					32		L	P	4,598	2	A	Miss	4,750
225	1									40		S	P	3,051	10	A	Hend	4,683
226	7				6							L	P	2,800	10	A	Miss	4,859
												S		4,834	19			
227	1				1					45		L	P	4,896	31	A	Ellenburger	5,100
228	4				4					42		L	P	4,853	28	A	Ellenburger	5,288
229	5		1		3					41		S	P	2,584	14	A	Ellenburger	5,288
230	4		1	2	1					44.5		L	P	4,988	17	A	Miss	4,955
231	3		1	1						44		L	P	4,841	19	A	Miss	4,865
232	3				3					38		L	P	3,847	15	A	Ellenburger	4,920
233	5		1		2					44		L	P	4,940	25	A	Miss	4,965
234	2			1	1					40		L	P	4,184	6	A	Ellenburger	4,768
235	6			1	5					40		S	P	2,177	8	A	Strawn	2,185
236	10	10			10					40		S	P	971	1	A	Cisco	1,103
237	4		2	2						42		L	P	3,338	20	A	Hend	3,637
238	3	3		2	1					44		L	P	4,396	31	A	Ellenburger	5,273
239	3	1			3					42		S	P	2,385	5	A	Marble Falls	4,586
240	3	3		2	1					42		L	P	4,756	15	A	Miss	5,085
241	23			1	19					43		L	P	4,290	22	A	Ellenburger	5,437
242	16	10		12	4					41		S	P	3,511	92	A	Ellenburger	5,437
243	9	1		4	5					39		L	P	3,857	7	A	Ellenburger	5,276
244	51			6	21					40		L	P	3,867	20	A	Ellenburger	5,442
												L		4,275	18			
245	1	1		1						44		L	P	4,820	36	A	Ellenburger	5,275
246	15			4	11					42		L	P	3,466	15	A	Miss	4,958
247	5		1	3	1					43		Cg	P	4,190	5	A	Miss	4,958
248	2			2						43		L	P	4,549	8	A	Miss	4,958
249	22	12		20	2					42		S	P	2,766	8	A	Miss	4,958
250	5				5					42		S	P	2,920	35	A	Ellenburger	5,292
												L		4,050	20			
251	35			4	1					40		L	P	3,762	38	A	Ellenburger	4,815
252	51		1	4	38					42		L	P	2,800	20	A	Miss	4,853
253	4			2	2					42		L	P	4,118	2	A	Miss	4,853
254	27	8		4	15					43		L	P	4,048	17	S	Miss	4,853
255	18			6	10					40		L	P	4,760	10	A	Miss	4,853
256	43		1	20	22					43		L	P	3,750	50	A	Miss	4,850
257	7	4		3	4					41.6		S	P	2,058	15	A	Hend	4,060
258	11	1		4	7					40		L	P	4,460	43	A	Ellenburger	4,839
259	6	3		2	4					44		L	P	3,635	10	A	Ellenburger	4,839
														4,181	14			
260	7		1	1	3					44		L	P	4,748	47	A	Ellenburger	6,035
261	3			2	1					44		L	P	4,679	12	A	Miss	4,691
262	5				5					42		S	P	3,622	15	A	Miss	5,265
263	13			3	9					42		L	P	3,831	11	A	Ellenburger	4,636
264	2				2					42.6		L	P	4,319	7	A	Ellenburger	4,636
265	9			3	3					42.5		L	P	4,179	31	A	Ellenburger	4,636
266	6				5					42.1		S	P	2,498	20	A	Ellenburger	4,636
267	3	1			3					42		Cg	P	4,304	7	A	Miss	4,822
268	2	2		1	1					42		L	P	4,966	13	A	Miss	4,989
269	2	1			1					44.1		L	P	4,249	11	A	Ellenburger	5,377
270	1	1		1						42		L	P	4,152	26	A	Marble Falls	4,178
271	8	1		4	4					43		L	P	4,242	17	A	Ellenburger	4,858
272	2	1			2					41		L	P	3,635	4	A	Miss	4,356
273	4	3		2	2					41		S	P	2,906	6	A	Miss	4,356
274	9	1		1	8					45		S	P	2,940	20	A	Ellenburger	5,246
												L		3,960	18			
												L		4,974	32			
275	2,950	105	74	57	2,078					40		x	P	x	x	A	Ellenburger	5,456
276	3,462	173	85	190	2,356													
	25,841	1,812	528	1,056	19,965													

IMPORTANT WILDCATS DRILLED IN 1949

LINE NUMBER	COUNTY OR LOCALITY	LOCATION	TOTAL DEPTH OR PLUG BACK METHOD	NAME OF OPERATOR — WELL NO. — FARM	DEEPEST HORIZON TESTED	INITIAL PRODUCTION PER DAY: OIL BBLS.	INITIAL PRODUCTION PER DAY: COMPLETION INTERVAL	CHOKE OR TUBING	FRACTURING AGENT USED	PRESSURE LBS. PER SQ. IN.: CASING	PRESSURE LBS. PER SQ. IN.: TUBING	REMARKS
1	Archer	Sec 1361 T E & L	5,131	Akin & Dimock #1 H. Campbell	Miss	120.5	L. 5056-75	12/64		405	620	Discovery
2	Archer	Sec 7 S P R R A-732	5,782	Hay Pet Co #1 Mc McGregor	Miss	46	L. 5479-84	16/64		600	80	Discovery
3	Archer	1834 T E & L	4,872	Bridwell O Co #1 J S Bridwell F	Caddo							D & A
4	Archer	W B Aldridge A-2	5,156	Bridwell O Co #3 J S Bridwell Jackson B	Strawn							D & A
5	Archer	Lot 62 Club Ranch	3,357	Bolin et al #1 C A Abercrombie	Canyon							D & A
6	Archer	Lot 52 Meade's L-M Pasture	5,136	L T Burns #2 D L Bishop	Caddo	481.44	L. 4644-48	20/64		580	140	Discovery
7	Archer	Lot 47 L P Hunt Sub	4,902	L T Burns #1 Dr A B Edwards	Caddo							D & A
8	Archer	Lot 4 Meade's L-M Pasture	5,300	L T Burns #1 F Firezina	Miss							D & A
9	Archer	Lot 89 Clark & Plum Blk 4	4,003	Carnation Pet Co #1 J D Carpenter								D & A
10	Archer	Lot 13 John Dorsey A-121	4,549	E B Clark #1 H O Prideaux	Caddo							D & A
11	Archer	W A Hassell A-755	3,723	L H Choate #1 A A Abercrombie	Strawn	458	Sd 3713-23	1/4		350	300	Discovery (Abercrombie Wilson Pool)
12	Archer	Lot 132 Club Ranch	4,952	Featherston et al #1 F Jehlik	Miss							D & A
13	Archer	Lot 2 N Thomas A-454	3,728	Featherston et al #1 W H Thomas	Strawn	72	Sd 3716-24	Pumping				Discovery (W. Archer City Pool)
14	Archer	Wm Gound A-796	5,539	Jack Grace #1 C L Abercrombie	Ellenburger							D & A
15	Archer	W A Keene A-1175	4,704	Geo W Graham #1 J T Gant		87.5	Sd 4723-28	Pumping				Discovery
16	Archer	I Kurnicky A-245	5,304	Geo W Graham #1 Emma Muir		10	L. 5215-58	Pumping				Discovery
17	Archer	Sec 20 H & T C Blk 1	5,675	Geo W Graham #1 L F Wilson H		34.78	L. 5192-5212	Pumping				Discovery
18	Archer	Sec 1 I & G N A-239	3,922	Jennings Dlg Co #1 J L Webb								D & A
19	Archer	Sec 44 A T N C L	5,286	Jennings Dlg Co #1 L F Wilson	Caddo							D & A
20	Archer	Lot 20 Clark & Plumb Blk 5	3,614	S D Johnson #1 J & F Henry		1,344	Sd 3607-13					Discovery
21	Archer	Lot 35 Clark & Plumb Blk 5	4,955	S D Johnson #1 F J Henry								D & A
22	Archer	Lot 7 L P Hunt Sub	4,733	G E Kadane & Sons #2 J M Bloodworth		15	OS 1306-25	Pumping				Discovery
23	Archer	Sec 7 H & T C Blk 3	5,235	G E Kadane & Sons #1 T B Wilson								D & A
24	Archer	Lot 8 L P Hunt Sub	4,674	G E Kadane et al #1 J M Bloodworth								D & A
25	Archer	Lot 18 Clark & Plumb Blk 5	3,608	J J Lynn #1 A J Denoss		302	OS 3598-3608			375	350	Discovery
26	Archer	Lot 32 Clark & Plumb Blk 5	4,210	J J Lynn #1 J L O'Keefe								D & A
27	Archer	Sec 48 A T N C L	4,618	J J Lynn #2 F Wilson								D & A
28	Archer	Sec 2601 T E & L	2,445	H C Lipscomb #2 Mrs L A Snider		60	OS 2430-45	Pumping				Discovery
29	Archer	Sec 2 S F I W A-848	5,210	J J Lynn #1 Jack Neale	Miss	144	L. 5198-5210	22/64		1035	500	Discovery
30	Archer	Lot 152 Harris Sub	4,915	Akin & Dimock #1 C L Abercrombie								D & A
31	Archer	John Richards A-368	3,874	Akin & Dimock #1 J H Turbeville		21	OS 3866-74	Pumping				Discovery
32	Archer	Sec 1840 T E & L	3,227	L T & Bobby Burns #1 W C Jones		100.24	OS 3209-23	Pumping				Discovery
33	Archer	W M Henry A-163	3,780	Fain-McGaha #1 W L King	Strawn	80	OS 3752-80	Pumping				Discovery King-Wilson
34	Archer	Sec 2 H & T C Blk 1	4,755	Fain-McGaha #1 W C Priebe		105	OS 4685-95	Pumping				Discovery
35	Archer	Sec 85 A T N C L	4,150	Fain-McGaha #1 L F Wilson								D & A
36	Archer	Lot 22 Jefferson Co Schld	5,597	D D Feldman #1 J H Turbeville	Ellenburger							D & A
37	Archer	Sec 53 A T N C L	5,774	Grace & Grace #1 L F Wilson F								D & A
38	Archer	Sec 20 H & T C Blk 1	5,675	Geo W Graham #1 L F Wilson H	Ellenburger	34.74	Miss L. 5192-5212	Pumping				Discovery
39	Archer	Sec 2 B B B & C A-1020	5,036	T F Hunter #1 T B Wilson	Miss	204	Miss L. 4988-5236	18/64		630	240	Discovery Hunter Bro.
40	Archer	Sec 7 H & T C Blk 1 A-217	3,868	T B Medders #1 M S Hancock A		336.87	OS 3854-68	25/64		50	40	Semi-Wild.
41	Archer	Sec 7 H & T C Blk 1 A-217	4,718	T B Medders #1 M S Hancock E		529	OS 4697-4718	32/64		300	60	Discovery
42	Archer	Sec 12 H & T C Blk 1	4,777	T B Medders #1 Mrs O M Fuller C		484	OS 4746-71	1/4		410	160	Discovery
43	Archer	H Corzine A-56	3,857	W J & John Moran #2 W B Hammond		336.04	OS 3855-57	1/4		400	65	Discovery
44	Archer	Sec 2 B B B & C A-1020	5,100	Mora Drilling Co #1 T B Wilson	Miss	96.60	Miss L. 4956-82	Open 2"				Discovery
45	Archer	Lot 16 J Dorsey A-122	4,240	Noranda Oil Co #1 H O Prideaux		141.84	OS 4218-40	Pumping				Discovery
46	Archer	Lot 3 Sec 59 A T N C L	3,976	Needl & Hood #1 L F Wilson A		840	OS 3962-76	1/2"		20	75	Discovery
47	Archer	Sec 9 A T N C L	4,005	Reno Oil Co #1-A L F Wilson "Staley"		42.1	Sd L. 3699-3750	Pumping				Discovery
48	Archer	Sec 2 S P R R A-921	3,927	Reno Oil Co #1 E T Brown A	Strawn	49.35	OS 3915-27	Pumping				Discovery
49	Archer	Sec 2 S P R R A-1210	4,015	Reno Oil Co #1 Baptist Foundation	Strawn	29.48	OS 3768-81	Pumping				Discovery (Reno-Bapt. st. Pool)
50	Archer	T Toby A-644	3,908	Reno Oil Co #1 L G Williams								D & A
51	Archer	Lot 20 Geraldine Sub	3,950	Reno Oil Co #1 L F Wilson "Goblke"	Strawn	253	OS 3895-3950	3/4		550	75	Discovery (Reno Strawn East Pool)
52	Archer	Lot 7 Coleman Sub	4,769	Sinclair O & G Co #2 W M Coleman		246.58	OS 4738-69	1"		300	50	Discovery
53	Archer	Lot 37	5,681	J W Sorrells & Suntex #1 W M Coleman	Miss							D & A
54	Archer	Lot 89 Jefferson Co Schld	4,916	Southern Pet Exp. Inc #1 G Bell								D & A
55	Archer	Lot 148 R. Carson A-103	3,833	Stewart Pet Co #1 J H Turbeville C	Strawn	90	OS 3828-33			370	140	Discovery
56	Archer	Lot 136 Harris Sub	1,175	Stewart & Grisham #2 B Wisdow Est.	Gunsite	55.35	OS 1168-75	Pumping				Discovery
57	Archer	Lot 14 Sec 30 A T N C L	1,413	Suntex Oil Co #1 A P Nichols	Gunsite	10	OS 1408-13	Pumping				Discovery
58	Archer	Lot 42 Clark & Plumb Blk 4	5,806	Konrad Satyshgold #1 T J Peyson	Ellenburger							D & A
59	Archer	Lot 13 McKinney & Williams A-305	5,191	The Texas Co #1 J B Ferguson		88.6	OS 3740-83	16/64		525	180	Discovery
60	Archer	Sec 1 S P R R A-403	5,438	The Texas Co #1 L F Wilson "C"		26.8	OS 2673-83	Pumping				Discovery
61	Archer	J J Hood A-181	2,683	Timberlake et al #1 C C Prideau	Strawn							T K S Pool
62	Archer	S H Smith A-370	3,806	Timberlake et al #1 E B Prideau	Strawn	532.84	OS 3708-31	3/4		500	300	D & A Discovery
63	Archer	B B B & C A-37	3,731	White & Duncan #1 Lena Maxwell A								D & A
64	Archer	H W Spivey A-451	2,394	Wilcox Oil Co #1 F Estridge		18.3	OS 4625-45	Pumping				Discovery
65	Archer	Lot 20 Clark & Plumb Blk 3	4,655	Frank Wood #2 N Schenk								D & A
66	Archer	Lot 12 Clark & Plumb Blk 4	5,202	Frank Wood #1 W J Schroeder	Caddo							D & A
67	Archer	Lot 14 Clark & Plumb Blk 4	5,240	Frank Wood #1 Joe Zotz	Caddo							
68		TOTAL WELLS 67				8,176.15						
69	Bay Lor	Sec 97 T & N O A-421	5,575	American Liberty O Co #1 J S Criswell		15	Lime 5162-72	Pumping				Discovery
70	Baylor	J H Barclay A 9	2,973	Humble O & R Co #1 Henry Penk	Canyon							D & A
71	Baylor	Sec 10 H & T C A-847	2,853	M L Richards #1 C H Taylor								D & A
72	Baylor	W H Dickerson A-184	5,709	Woods & Cox #1 W H Portwood	Ellenburger							D & A
		TOTAL WELLS 4				15						

IMPORTANT WILDCATS DRILLED IN 1949

LINE NUMBER	COUNTY OR LOCALITY	LOCATION	TOTAL DEPTH, FT. OR METERS	NAME OF OPERATOR — WELL NO. — FARM	DEEPEST HORIZON TESTED	INITIAL PRODUCTION PER DAY: OIL, BBL.	INITIAL PRODUCTION PER DAY: COMPLETION INTERVAL	CHOKE, FRACTION OF AN INCH	PRESSURE, LB. PER SQ. IN.: CASING	PRESSURE, LB. PER SQ. IN.: TUBING	REMARKS
73	Clay	Lot 18 Hopkins Co Schld	4,725	Akin & Dusock #1 G B Chapman		72	OS 4644-64	Pumping			Discovery
74	Clay	H Devers A-887	6,121	Akin & Dusock #1 E B Nutter	Ellenburger						D & A
75	Clay	Lot 2 J H Belcher Sub	4,715	Akin & Dusock #1 N D Threadgill							D & A
76	Clay	F Houston A-196	5,787	Barnsdall Oil Co #1 H Zachary	Ellenburger						D & A
77	Clay	Sec 2636 T E & L	5,625	L T Burns #1 J D Copeland							D & A
78	Clay	Sec 2683 T E & L	5,263	L T Burns #2 J B Dale Est	Caddo						D & A
79	Clay	Lot 43 J H Belcher Sub	4,654	L T Burns #1 Cora Fletcher	Strawn						D & A
80	Clay	Lot 43 J H Belcher Sub	4,598	L T Burns #2 Cora Fletcher	Strawn	239.22	OS 4476-91	20/64	220	105	Extension
81	Clay	Lot 44 J H Belcher Sub	4,509	L T Burns #1 S L Fulghum	Strawn	237	OS 4474-4509	16/64	525	100	Extension
82	Clay	Lot 58 Ward & Houssells	4,673	L T Burns #11 Wm McGregor Est	Strawn	220.63	OS 4658-68	16/64	470	160	Extension
83	Clay	Jas Cook A-751	4,370	C B Christie #1 E Spikes	Strawn						D & A
84	Clay	Lot 56 J H Belcher Sub	5,385	Consolidated & Premier #1 J H Windle	Caddo						D & A
85	Clay	Sec 48 H T & B A-954	6,503	Continental Oil Co #1 W P Ferguson A	Ellenburger						D & A
86	Clay	Sec 1 H & T C A-253	5,975	Continental Oil Co #2 L M Staley	Ellenburger	98	Lany Gong 5903-21	Pumping			Discovery
87	Clay	Lot 4 J H Belcher Sub	4,550	Dillard-Waltermire #1 W I Holt	Strawn	64.70	OS 4487-4504	Pumping			Extension
88	Clay	Lot 59 J H Belcher Sub	4,492	Fain & McGaha #1 S L Fulghum	Strawn	126	OS 4487-92	Pumping			Extension
89	Clay	Sec 5 B B B & C A-51	4,928	Fain & McGaha #2 Hoss H & S D							D & A
90	Clay	T Toby A-691	5,604	Jack Grace Prod Co #3 D M Cobb	Caddo	137.5	L 5591-5604	1/2	400	25	Discovery
91	Clay	Lot 19 Grayson Co Schld	5,946	Jack Grace Prod Co #1 W C Fields	Caddo	168	Lany Gg 5921-46	12/64	550	175	Discovery
92	Clay	Lot 5 Clark & Plumb Blk 1	5,391	S D Johnson #1 Mrs B Miller		451.2	Lany Gg 5380-91	12/64	520	520	Discovery
93	Clay	J J Head A-175	4,801	E B Madden #1 A B Seigler							D & A
94	Clay	Lot 22 Halsell Sub #2	4,961	Jack Story #1 Dr A B Edwards							D & A
95	Clay	Sec 19 H T & B A-218	6,195	Gulf Oil Corp #1 Geo Scaling A	Ellenburger	1,248	Caddo L 5575-5700	3/4	620	340	Discovery (Lazy B)
96		TOTAL WELLS 22				3,062.25					
97	Cooke	S A & M G A-974	3,756	Atlantic Refg Co #1 John Rivoire	Strawn	33	OS 3741-58	Pumping			Discovery
98	Cooke	A Kennedy A-550	4,007	J W Baldwin #1 I B Hudlong							D & A
99	Cooke	Sec 11 S P R R A-970	2,879	Brodwell Oil Co #1 Ada Williams							D & A
100	Cooke	H Edmanston A-354	4,335	Britton Dlg Co #1 W D McMenamy							D & A
101	Cooke	Rana Dye A-317	4,522	Britton & Fitzhugh #1 B V McCorkle		147	OS 4515-22	Pumping			Discovery
102	Cooke	Jas Bolin A-40	1,592	Brett Brodsy #1 L B Holland	Ellenburger						D & A
103	Cooke	Lot 4 T Scott A-900	1,732	T P Frost #1 Joe Koelzer		14	OS 1717-32	Pumping			Discovery
104	Cooke	H O Kohlman A-544	2,600	Clark & Cowden #1 W J Kleine	Ellenburger						D & A
105	Cooke	J Friedman A-874	3,367	Dillard & Seitz #1 Iola Johnson	Ellenburger	25	OS 1618-34	Pumping			Discovery
106	Cooke	Mary Alexander A-6	2,064	Fleet Dlg Co #1 L Campbell							D & A
107	Cooke	T G Murphy A-671	1,969	Fair & Scott #1 Paul Rivoire		10	OS 1929-42	Pumping			Discovery
108	Cooke	T Bell A-52	2,392	H B Hollandsworth #1 M W Thompson	Granite		1 Mi Gas Gas Sd 1980-85				Discovery
109	Cooke	H Walker A-1082	3,510	Harvey Dlg Co #1 A B Sicklall	Ellenburger						D & A
110	Cooke	H Baker A-100	4,515	Harvey Dlg Co #1 E B Haynes		42	OS 4276-87	Pumping			Discovery
111	Cooke	Jas. Bradshaw A-31	2,578	S D Johnson #1 W B Cannon		189.18	OS 2755-58	2"	60	55	Discovery
112	Cooke	T Scott A-900	2,061	H D Kahn #1 Joe Magers	Ellenburger						D & A
113	Cooke	Lot 92 Fannin Co Schld	6,441	Kay Kimbell #1 L C Bacon							D & A
114	Cooke	Rana Dye A-317	4,741	Kay Kimbell #1 W F Craver							D & A
115	Cooke	Asa Hartfield A-438	4,924	Kay Kimbell #1 S R Thebold							D & A
116	Cooke	Lot 85 Fannin Co Schld	6,663	Kay Kimbell #1 A L Williams							D & A
117	Cooke	Lot 84 Fannin Co Schld	5,867	Kay Kimbell #1 W E Winger		210	OS 5861-67	Pumping			Discovery
118	Cooke	Lot 25 Fannin Co Schld	3,612	Kimbell-Sims #1 Geo Anderson		152	OS 3603-12	Pumping			Discovery
119	Cooke	M D Lynch A-609	2,645	Kimbell-Sims #1 T H Clark							D & A
120	Cooke	H Nail A-790	1,544	E L Leslie #1 R Kirby	Ellenburger						D & A
121	Cooke	N B Reed A-869	3,003	P G Lake Inc #2 J B Pace	Ellenburger	15	OS 2675-87	Pumping			Discovery
122	Cooke	Lot 24 Fannin Co Schld	3,641	Magnolia Pet Co #1 J W Lister		73.79	OS 3624-30	Pumping			Discovery
123	Cooke	Wm Phelps A-821	2,106	Russell Maguire #1 C F Bundy		40	Sdy Lime 1914-26	Pumping			Discovery
124	Cooke	Sec 15 S P R R A-975	2,505	Russell Maguire #1 J Kreitz							D & A
125	Cooke	B F Baker A-1181	5,225	Vence Powell #1 Addie Ware	Ellenburger						D & A
126	Cooke	J W Lowery A-562	1,647	F R Robinson #2 Ben Sandman	Ellenburger						D & A
127	Cooke	James Taylor A-1007	1,296	Wm H Houzer #1 P Hensel	Ellenburger						D & A
128	Cooke	G DeLos Santos A-894	4,028	J R & Adn Seitz #1 N Mitchell		46	OS 4020-28	Pumping			Discovery
129	Cooke	E Yeamans A-1173	3,017	J R & Adn Seitz #1 J B Pace	Ellenburger						D & A
130	Cooke	W L Wheelock A-991	1,655	Smoddy et al #1 M McCubbin	Ellenburger						D & A
131	Cooke	Sec 2 University Lg 7 A-1452	2,755	Snuggs & Neal #2 G A Lemaster		119	OS 2748-55	24/64		200	Discovery
132	Cooke	Sec 2 University Lg 7 A-1452	5,574	Snuggs & Neal #2 G A Lemaster "A"		48	OS 3374-84	Pumping			Discovery
133	Cooke	O Martin A-653	4,120	Theck & Cross #1 Fred Hickman	Ellenburger						D & A
134	Cooke	B F Carpenter A-229	1,632	Theck & Cross #1 A B Zwingo	Ellenburger	21	OS 1624-32	Pumping			Discovery
135	Cooke	E Mallard A-647	3,070	Trimuter Pet Co #1 G E Geyn	Ellenburger						D & A
136	Cooke	S R Knight A-559	2,390	Utex O Co #1 T G Moss	Granite						D & A
137	Cooke	T Cook A-258	1,250	O K Ekkerckson #1 J A Wylie	Ellenburger						D & A
138		TOTAL WELLS 41				1,184.97					
139	Denton	D Boone A-100	1,556	Harrigan Bros #2 J P Knox		71	OS 1552-56				Discovery
140	Denton			H L Hunt #2 A H Johnson							
141	Denton	J W Gibbons A-445	1,881	Murray Inv. Co #1 C Waide	Ellenburger						D & A
142	Denton	B F Lynch A-725	1,650	F Scharf #1 A O Mason	Ellenburger						D & A
143	Denton	J W Simpson A-1140	2,791	Sussex O Co #1 M H Brown	Ellenburger						D & A
144	Denton	L H McNeil A-845	7,309	Standard O Co-Kas. #1 E D Hart	Ellenburger						D & A
145		TOTAL WELLS 6				71					
146	Jack	M B Lord A-1924	5,142	Brodwell O Co #1 J B Halsell A	Mis						D & A
147	Jack	J Irvin A-1625	5,675	Cox Drlg Co #1 W L Graham	Ellenburger						D & A
148	Jack	W A Price A-1708	6,066	Cox Drlg Co #1 D Hensley	Ellenburger						D & A
149	Jack	Sec 3326 T E & L	5,727	Cox Drlg Co #1 J T Honey	Ellenburger	37.48	L & S 4582-4602		990	700	Discovery
150	Jack	M Allen A-9	5,505	Davon Oil Co #1 W E Crow	Caddo						D & A
151	Jack	J Poitevent A-1776	4,542	J B Devine #1 E Estherly		126	L 4480-97		600	100	Discovery
152	Jack	J U Fields A-218	5,508	Glasscock & Pontiac #1 R L Morris		480	Cg 5406-26			400	Discovery
153	Jack	W Heutzel A-511	5,830	Hanlon-Boyle Inc #1 I L Dodson	Ellenburger						D & A

IMPORTANT WILDCATS DRILLED IN 1949

LINE NUMBER	COUNTY OR LOCALITY	LOCATION	TOTAL DEPTH FT. OR METERS	NAME OF OPERATOR	WELL NO.	FARM	DEEPEST HORIZON TESTED	INITIAL PRODUCTION PER DAY		CHOKE OR FRACTURE TREATMENT	PRESSURE LBS. PER SQ. IN.		REMARKS
								OIL BBLS. GAS MCF	COMPLETION INTERVAL		CASING	TUBING	
154	Jack	J W William A-877	4,588	Hanlon-Hoyle Inc	#1	B Moore		336	L 4561-88	16/64	1,200	525	Discovery
155	Jack	J H Maxwell A-1143	6,190	Jack Grace Prod Co	#1	D Lindsey	Ellenburger						D & A
156	Jack	B Green A-1684	5,637	Jack Grace Prod Co	#1	Garrett							D & A
157	Jack	J M Hudson A-310	6,231	Jack Grace Prod Co	#1	L L Caraway		240	Cg 5492-5504	1/2"	875	225	Discovery
158	Jack	M Akin A-918	6,250	J J Lynn	#1	E Wilkinson	Ellenburger						D & A
159	Jack	T Burbridge A-68	4,712	Russell Maguire	#1	T H Cherry-homes		352	Cg 4692-4712	1/2"	600	250	Discovery
													Discovery
160	Jack	S A & M G A-585	4,458	Russell Maguire	#1	M U Johnston		2,800,000 gas	Sd 4440-45				Discovery
161	Jack	Lot 21 Henderson C S L	4,893	Russell Maguire	#1	H L Roper		151.7	L 4570-85	16/64	480	100	Discovery
162	Jack	S H Hazel A-256	6,342	Mid-Cont. Pet Corp	#1	B E & J F Boyd A	Ellenburger	533	L 6225-6342	26/64	350	725	Discovery
163	Jack	M W Thompson A-194	6,415	Mid-Cont Pet Corp	#1	C E Caraway	Ellenburger	616	L 6335-57	1/4	750	1175	Discovery
164	Jack	J J Shelton A-596	6,898	Mid-Cont Pet Corp	#1	T E Davis	Ellenburger						D & A
165	Jack	H Lewis A-347	3,860	Mid-Cont Pet Corp	#1	W M Killen		124.7	OS 3792-95	1/2	360	210	Discovery
166	Jack	J Irvin A-313	6,649	Mid-Cont Pet Corp	#1	Roy Cherry-homes	Ellenburger	306	L 6637-49	20/64	700	300	Discovery
167	Jack	H Lewis A-347	6,290	Mid-Cont Pet Corp	#2	W M Killen	Ellenburger	315.77	L 6240-58	4/64	1,000	750	Discovery
168	Jack	J H Kirkpatrick A-1128	6,581	Mid-Cont Pet Corp	#1	B Zuber	Ellenburger						
169	Jack	L L McKinley A-1557	5,810	Newman Bros	#1	T H Cherry-homes	Caddo	2,000,000 gas	Cg 5730-66				Discovery
170	Jack	Lot 31 Wood Co Schld	6,465	Sorrells O Co	#1	A D Caraway	Ellenburger						D & A
171	Jack	Mc Hill A-1964	4,828	Star O Co	#1	Haley-Henderson Unit		2,425,000 gas	L 3936-56				Discovery
172	Jack	J C O'Connor A-454	6,720	Star O Co	#1	Cherry-homes	Ellenburger	311.44	Cg 5472-90	2"	600	200	Discovery
173	Jack	J C Gardner A-233	4,652	Star O Co	#1	J B Rutledge		183		22/64	450	350	Discovery
174	Jack	John Little A-2272	6,051	Warren O Co	#1	Gresham-Davis	Ellenburger	193	L 5695-5780	14/64	800	280	Discovery
175	Jack	Lot 4 Navarro C S L	5,804	Warren O Co	#1	C O Tolgfman	Ellenburger	492	L 5490-5408	23/64	2,000	1160	Discovery
176		TOTAL WELLS 30						5,128.09					
177	Knox	Sec 71 D & W Blk 2	6,105	Humble O & R Co	#1	Joe Voss	Ellenburger						D & A
178	Knox	Sec 51 D & W Blk 2	6,186	Stanolind O & G Co	#1	M Baker	Ellenburger						D & A
179		TOTAL WELLS 2											
180	Montague	Sec 28 E T B R	6,690	C U Bay	#1	D C Gregory	Marble Falls	173	Caddo Lime 6165-90				Discovery
181	Montague	J Winn A-808	6,327	Carraway & Bundy	#1	J P Cunningsmith	Bend	900.86	Cg 6292-6302	1/2"	950	450	Discovery
182	Montague	Blk 67 Pamola Co Schld	6,248	T J Carter	#1	W B Robertson	Marble Falls						D & A
183	Montague	Lot 51 Belcher Sub	5,712	S O Johnson	#1	M Reynolds	Ellenburger						D & A
184	Montague	Lot 33 Belcher Sub	6,086	Gulf Oil Corp	#1	M E McDonald	Ellenburger						D & A
185	Montague	J O'Leary A-1314	5,098	Jack Grace Prod Co	#1	E Scago	Bend	228	Cg 5077-82	16/64	625	180	Discovery
186	Montague	Lot 81 Belcher Sub	5,893	Tex Harvey O Co	#1	B Capps	Bend	35	L & Cg 5586-5700	Pumping			Discovery
187	Montague	Sec 62 E T B R A-563	6,371	The Texas Co	#1	W E Hass		427.2	L 6255-6300	1/2"	225	80	Discovery
188	Montague	W Neathery A-566	5,478	Whitsett et al	#1	C Maddox	Bend	3,000	Cg 5370-84	1/2	700	500	Discovery
189		TOTAL WELLS 9						4,764.06					
190	Wichita	Sec 2 Denton Co Schld L-2 A-57	4,493	Armour Properties	#1	W J House							D & A
191	Wichita	Lot 15 Cosbird Sub	4,161	Chapman-McFarlin	#1	J. Hopkins							D & A
192	Wichita	Blk 190 Waggoner Colony Sub	2,438	Fortex Oil Corp	#1	W Beasley		100	OS 884-94	Pumping			Discovery
193	Wichita	Sec 1 S P R R A-266	4,215	Alexander Goldsmith	#1	F Daune		143	OS 4037-50	12/64	150	120	Discovery
194	Wichita	J C Pike A-509	6,008	Continental O Co	#1	H Hausler		181	L 5648-90	Pumping			Discovery
195	Wichita	Lot 19 Cherokee Co Schld	4,683	W H Hannon	#1	L T Cooke "A"		596.4	OS 4861-83	24/64		750	Discovery
196	Wichita	Lot 21 Denton Co Schld	4,034	Perkins & Gillan	#1	L Chilson B		386.22	OS 4017-34	2"	95	60	Discovery
197	Wichita	Lot 5 J E Parker Sub	3,969	J L Swanner	#1	W M Short		184.89	OS 3950-69	20/64	350	80	Discovery
198		TOTAL WELLS 8						1,591.51					
199	Wilbarger	Sec 32 H & T C Blk 4	3,929	Geo Shanor & Cit Service		W T Waggoner	Ellenburger	357	Dolo 3910-29	1/4	450	150	Discovery
200	Wilbarger	Sec 21 H & T C Blk 3	4,816	W T Waggoner	#2	W T Waggoner TT	Ellenburger	480	L 4805-16	1/4	500	350	Discovery
201		TOTAL WELLS 2						837					
202	Wise	N Isaacs A-454	8,061	Cities Service	#1	E T McKissick	Ellenburger						D & A
203	Wise	Mc Beckwell A-38	5,950	J C Man et al	#1	J D Hamilton	Bend						D & A
204	Wise	W M Burke A-30	7,226	Mid-Cont Pet Corp	#1	M S McBride	Ellenburger						D & A
205	Wise	Sec 48 M E P & P A-1151	3,085	Sugnal & Loffland	#1	Dr J Daly Unit 2	Bend	45	L 3870-85	19/64			Discovery
206	Wise	Geo A Frazier A-993	6,590	Sugnal & Loffland	#1	H Burton Unit 1	Ellenburger	192	L 3835-70	10/64			Extension
207	Wise	W A Gorman A-1125	5,562	B B Thrift	#1	W O Blocker		227.04	Lv Cg 5492-5520	1/2"		250	Discovery
208		TOTAL WELLS 7						464.04					
209	Young	Lot 16 Young Co Schld A-1285	3,713	Armour Properties	#1	G B Carmack	Bend	72	L 3690-94	2"	500	250	Discovery
210	Young	J Sanders A-251	2,619	Allar Co	#1	Watson Bros		149	OS 2615-19	1/2	200	85	Discovery
211	Young	Sec 2357 T E & L	4,587	Bishop Oil Co	#1	B F Mueller	Mix	183.42	Caddo Lime 3738-48	1/4		425	Discovery
212	Young	Sec 253 T E & L	3,670	L T Burns #1	J F Larmore		Bend	242	OS 2874-2905	Pumping			Discovery
213	Young	Sec 242 T E & L	5,010	L T Burns	#1	J C Tsack	Bend						D & A
214	Young	Sec 762 T E & L	4,089	Dark Hoy Co	#1	B J Hulse	Mix						D & A
215	Young	Sec 1400 T E & L	4,900	Cato Oil Co	#1	F J Leslie	Bend	239	L 4451-4514	25/64	475	75	Discovery
216	Young	Sec 1 J Poitevent A-227	3,115	C B Christie	#1	M K Graham A		30	OS 3074-3115	2"			Discovery
217	Young	Sec 2373 T E & L	4,800	Cities Serv Oil Co	#3	T L Mayes	Ellenburger	319.84	Caddo Lime 3705-15	20/64		490	Discovery
218	Young	Sec 3410 T E & L Frac C	4,014	A B Dillard	#1	M K Graham	Bend						D & A
219	Young	Lot 25 Young Co Schld A-1285	3,736	Goodstein & Gordon	#1	J M Golden	Bend	35.22	OS 2594-2616	Pumping			Discovery
220	Young	B F Fisher A-95	4,751	Hanlon-Hoyle Inc	#1	V Holcomb	Ellenburger						D & A
221	Young	A McMillen A-198	2,985	Howell & Howell	#1	N & S Prideaux		146.81	Lime & OS 2974-85	Pumping			Discovery
222	Young	Sec 174 T E & L	3,370	Hunter Bros	#1	V B Hankel		984	OS 3360-70	3/4	220	300	Discovery
223	Young	Sec 770 T E & L	5,183	Humble O & R Co	#1	W D Bass	Ellenburger	57	L 4361-71	Pumping			Discovery
224	Young	Sec 1672 T E & L	2,912	Hanlon-Hoyle Inc	#1	K D Oates		202	OS 2906-12	16/64	280	260	Discovery

IMPORTANT WILDCATS DRILLED IN 1949

LINE NUMBER	COUNTY OR LOYALTY	LOCATION	TOTAL DEPTH, FT. OR METERS	NAME OF OPERATOR	WELL NO.	FARM	DEEPEST HORIZON TESTED	INITIAL PRODUCTION PER DAY: OIL, BBLS. OR GAS, MCF	COMPLETION INTERVAL	DATE COMPLETED OR P & A	PRESSURE LB. PER SQ. IN.: CASING	TUBING	REMARKS
225	Young	Sec 316 T E & L	4,771	R C Lipscomb	#1	Adam Parr et al	Mis	259.1	L 4756-71	14/64	150	530	Discovery
226	Young	Sec 301 T E & L	4,989	R C Lipscomb	#1	W T Swink A		118	L 4966-89	8/64	710	625	Discovery
227	Young	Sec 465 T E & L	4,651	Nu Enamel O Corp	#1	H L Morrison	Mis	129	L 4632-51	8/64	550	100	Discovery
228	Young	H Hodges A-134	3,753	Nu Enamel O Corp	#1	John E Morrison							D & A
229	Young	H M Jones A-1612	4,505	Panhandle P & R Co	#2	W Brundage		149		1/4	210		Discovery
230	Young	Sec 54 T E & L	5,275	Pure Oil Co	#1	J K Jeffery	Ellenburger	194	Mis Lime 4820-56	14/64	575	275	Discovery
231	Young	Sec 2 J Poitevent A-2206	4,465	Ben Rankin	#1	S A Clark		30	DS 3972-93	1/16	450	75	Discovery
232	Young	Sec 2 J Poitevent A-1901	4,636	Signal Oil & Rankin	#1	Hunt & Graham	Mis	188	Mis Lime 4622-36	12/64	680	200	Discovery
233	Young	Sec 4 B B B & C A-1701	4,349	Sinclair Oil Co	#1	C F Kunkel	Bend	194.64	L 4328-45	Pumping			Discovery
234	Young	Sec 1201 T E & L	3,395	Star Oil Co	#3	L F Evans	Bend	4,000,000	L 3334-46		1190		Discovery
235	Young	W C Hall A-1964	4,774	Star Oil Co	#1	S Bailey	Mis	216	L 4764-74	12/64		50	Discovery
236	Young	J N Taylor A-1243	4,585	Star Oil Co	#1	Minta Wright		15	L 4565-70	Pumping			Discovery
237	Young	Sec 1212 T E & L	4,730	T-P Coal & O Co	#1	G L Dunnell	Ellenburger	13,500,000	Sd 4087-93				Discovery
238	Young	H K Glass A-1438	4,796	T-P Coal & O Co	#1	S H Stoker A	Ellenburger						D & A
239	Young	Sec 2701 T E & L	5,374	Woods & Cox	#1	W C Mobley	Ellenburger						D & A
240	Young	Sec 2 B B & C A-1721	5,635	Woods & Cox	#1	H. Shanafelt "C"	Ellenburger						D & A
241	Young	Sec 1653 T E & L	3,639	Warren Oil Co	#1	Allar Co K	Bend	174.2	Sd 3635-39	20/64	400	60	Discovery
242	Young	Sec 2179 T E & L	4,311	Warren O Corp	#1	B T Sweeney B	Bend	251.69	Cg 4304-11	1/2	875	340	Discovery
243		TOTAL WELLS 34						4,578.92					
		GRAND TOTAL WELLS 212						29,872.99	bbl per day				

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1949	72	28
Number of oil wells completed during 1949	1,398	123
Number of gas wells completed during 1949	6	9
Number of dry holes completed during 1949	926	253

Fig - 1

TABLE NO. 3

Completions & Abandonments - Year 1949

NORTH TEXAS

County	Oil Wells	Initial Prod.	Gas Wells	Dry Holes	Total Tests
Archer	496	49,607	-	384	880
Baylor	15	372	-	8	23
Clay	97	23,347	-	88	185
Cooke	92	15,083	2	106	200
Denton	29	3,683	-	24	53
Foard	-	-	-	-	-
Hardeman	-	-	-	-	-
Jack	121	35,803	9	75	205
Knox	-	-	-	8	8
Montague	129	20,590	-	85	214
Wichita	347	33,450	-	219	566
Wilbarger	30	3,199	-	42	72
Wise	41	10,253	2	15	58
Young	124	14,477	2	125	251
TOTALS	1,521	209,864	15	1,179	2,715

TABLE NO. 4

Discoveries for the year 1949

NORTH TEXAS DISTRICT
(Railroad Commission District No. 9)

County	No. of Fields	Combined I. P.
Archer	43	7,034
Baylor	1	15
Clay	13	2,541
Cooke	10	745
Denton	2	77
Foard	-	-
Hardeman	-	-
Jack	15	3,680
Montague	16	5,405
Wichita	11	2,623
Wilbarger	3	635
Wise	4	607
Young	10	2,105
TOTALS	128	25,467

TABLE NO. 6

ORDOVICIAN ACTIVITIES

There were 71 tests drilled to the Ordovician during 1949 in North Texas (Railroad Commission District No. 9). Outcome of these tests is shown by the following tabulation:

County	Dry Holes Testing Ellenburger	Oil Wells Comp. in Ell.	I.P.	Wells Testing Ell. but Comp. In Shallow Pay	Total Ellen. Tests
Archer	2	2	99.5	2	6
Baylor	1	-	-	-	1
Clay	-	1	66	1	2
Cooke	17	-	-	-	17
Denton	4	-	-	-	4
Foard		-	-	-	-
Jack	9	6	2456.77	1	16
Knox	2	-	-	-	2
Montague	3	2	173	-	5
Wichita	2	1	35	1	4
Wilbarger	1	2	737	1	4
Wise	2	1	192	1	4
Young	2	2	355	2	6
TOTALS	45	17	4114.27	9	71

TABLE NO. 5

New Fields as Designated by the Railroad Commission.

For the year 1949 in District No. 9

County & Field	Total	Initial Prod.
Archer		
Abercrombie Wilson		458
King-Wilson		80
Reno Baptist		28.48
Reno Strawn		253.13
T. K. S.		268
West Archer City		72
Vogtsberger Strawn		372.96
TOTAL	7	1,533.57
Clay		
Lazy B		1,248
TOTAL	1	1,248
Cooke		
Lemaster		119
Kimbell-Sims		152
TOTAL	2	271
Denton		
Bolivar North		3
Bolivar South		74
TOTAL	2	77
Jack		
Post Oak		124
Campsey Ellenburger		616
Hanlon Caddo		34
Campsey East Ellenburger		533
Gresham Ellenburger		192.93
Post Oak Ellenburger		315.77
Rusmag		151.7
Tilghman Mis Lime		822
TOTAL	8	2,789.4
Montague		
Haws		427.2
Minor-West		900.86
Richardson Caddo		1,000
TOTAL	3	2,328.06
Wilbarger		
Baker		62.53
Greyback Ellenburger		356.48
O'Dell Ellenburger		216
TOTAL	3	635.01
Wise		
Daly Caddo		45
TOTAL	1	45
Young		
Allar-Warren Caddo		129
Fish Creek Mis		60
Furr & Allar		259.1
Jeffery		194
Swink		118
Turner & West		312
TOTAL	6	1,072.1
GRAND TOTALS	33	9,999.14

TABLE NO. 7

Refineries in the North Texas District

1949

Company	Location	Capacity	Daily Avg Thruput
Bryson PL & Rfg. Co.	Bryson	1,200	522
Continental Oil Co.	Wichita Falls	10,950	6,774
Jacksboro Rfg. Co.	Jacksboro	250	83
LaSalle Pet. Corp.	Burkburnett	1,500	898
Muenster Rfg. Co.	Muenster	750	-
Panhandle Rfg. Co.	Wichita Falls	6,950	2,970
Tucker Oil Co.	Burkburnett	250	-
Tydal Rfg. Co.	Gainesville	2,000	430
Ute Rfg. Co.	Graham	700	580
Waggoner Rfg. Co.	Electra	9,000	3,737
TOTALS		33,550	15,994

TABLE NO. 8

Natural Gasoline Production 1949

North Texas - Railroad Commission District No. 9

Location	No. Of Plants December	Production Barrels For the Year 1949
Archer County		
Moncrief & Sons	1	-
Warren Pet. Corp	1	662,400
TOTAL	2	662,400
Jack County		
Panhandle P & R Co.	1	2,300
Warren Pet. Corp	1	29,800
TOTAL	2	32,100
Montague County		
Continental	1	5,100
Highlander Gasl. Co.	1	55,100
TOTAL	2	60,200
Wichita County		
Bell Oil & Gas Co.	1	1,400
Continental Oil Co.	1	881,400
Magnolia Pet Co.	1	39,900
Moncrief & Sons	1	18,700
Phillips Pet Co.	1	442,500
Skelly Oil Co.	2	43,000
The Texas Co.	2	177,800
Tucker Oil Co.	1	7,700
Warren Pet Corp	1	141,500
TOTAL	11	1,753,900
Wilbarger County		
Magnolia Pet. Co.	1	45,000
Waggoner Gas Co.	1	48,200
TOTAL	2	93,200
Young County		
Chas. E. Knox	1	15,900
Nash Gasl. Co.	2	68,100
TOTAL	3	84,000
GRAND TOTAL	22	2,685,800

TABLE NO. 9

Drilling Operations by Counties

As of December 31, 1949

North Texas - Railroad Commission District No. 9

	In Proven Fields Locations Staked	Tests Drilling	Wildcat Tests Drilling	Total Operations
Archer	26	55	5	86
Baylor	2	2	-	4
Clay	5	16	1	22
Cooke	5	9	1	15
Denton	6	8	1	15
Foard	-	-	-	-
Hardeman	-	-	2	2
Jack	6	20	1	27
Knox	-	-	5	5
Montague	5	15	6	26
Wichita	31	9	1	41
Wilbarger	1	-	-	1
Wise	10	5	7	22
Young	1	13	1	15
TOTALS	98	152	31	281

Oil And Gas Developments In The Atlantic Coastal Plain During 1949

By E. W. BERRY, * Member AIME

During 1949 there has been little active drilling in the Atlantic Coastal Plain from New Jersey to South Carolina.

No drilling was done in New Jersey, Delaware, and the Coastal Plain of Maryland and Virginia. Leasing activities in these States are not available.

NORTH CAROLINA

The Pambo Drilling Co., drilling for the Connell interest has a rig, shut down, on the west side of the highway between Winton and Harrellsville, Hertford County. This hole is probably at or near basement at 1300± ft. There has been no activity on the property since May 1949, but the hole is not officially plugged. A rig was reported moved into Onslow County, in December, 1949, (it actually got there in May, 1950). Active leasing was under way in 1949. The State Owned Lands east of longitude 78° and south of a line between Ocracoke Inlet and New Bern have been re-leased to the Coastal Plain Oil Co., and various private leases were taken. It is rumored that about one million acres were under lease Dec. 31, 1949. No drilling on these leases in 1949.

*Department of Geology, Duke University, Durham, North Carolina.

Manuscript received at the office of the Institute, June, 1950.

SOUTH CAROLINA

Aiken County: An attempt to drill for oil is rumored near Wagner, but it is unconfirmed.

Horry County: A rig is still up on Fanny Collins No. 1, south of Conway, but no drilling has been done. The hole was cased and perforated, but the cement failed and the test was not conclusive. Depth 1439 ft in hard sandstone.

Orangeburg County: A hole about 300 ft deep was reported near Springfield and is supposed to be still active.

The State of South Carolina and a citizen of South Carolina signed a two year lease on Feb. 4, 1949, covering approximately 570 sq mi of state owned land; 365,000 acres are in the "tideland coastal area" and 450,000 acres in the "inland submerged land." More or less private leasing has gone on, but the exact amount is unknown. Activity is promised for 1950.

ACKNOWLEDGMENTS

The author is indebted to the following individuals for information contained in this report: Meredith E. Johnson, State Geologist of New Jersey; J. T. Singewald, Jr., State Geologist of Maryland; and W. M. Mc Gill, State Geologist of Virginia.

The Drift of Things

. . . as followed by **EDWARD H. ROBIE**
Secretary AIME

Start of the Korean War

A first-hand account, from an AIME member, of the first few days of the Korean War as experienced by a resident of Seoul was received late in July. The writer, Don L. Carroll, was for a time associate editor of *Oil Weekly*, and recently has been with the Oil and Gas Division of the Department of the Interior. He was a member of the ECA mission to Korea. His wife, Catherine, and children were with him in Seoul when the war started.

"My first intimation of trouble came early on Sunday afternoon, June 25, when I was called to the Embassy and told that the North Korean Army had crossed the border in force, 30 miles away. While this was the largest scale operation yet reported on the border, we were told that the South Korean forces would undoubtedly shoo them back to the north within a matter of hours, as they had done repeatedly before.

"As a precaution, we were advised to make initial preparations to evacuate and to make plans to destroy documents, correspondence and records, in case the situation should become more serious. I returned home and told Catharine and the children to pack hand luggage and secrete our most valuable possessions in attic and basement corners. I then returned to the office and sorted my files as instructed by the Ambassador.

"The evening news was encouraging and our military observers at the front reported that the enemy reconnaissance forces had been stopped. During the night, however, enemy infiltrations succeeded in cutting communications between Korean Army units, and confusion began to develop. By 2:30 a.m. Monday, the enemy forces had penetrated to within 17 miles of Seoul, and the Ambassador issued the order to evacuate wives and children to Ascom, about halfway to the port at Inchon. This assured easier evacuation from Seoul itself in case of eventual full evacuation of all Americans in Korea. By 6 p.m. of the same day, all dependents had been placed aboard the Norwegian freighter *Reinhold* in Inchon harbor. C rations, blankets, water, etc., were loaded aboard and the ship sailed for Japan an hour later. Fighter planes had been sent over from Japan to cover the whole operation and to escort the ship at sea.

"This protection was necessary because Communist planes had been strafing Seoul, Inchon, and the airports at nearby Kimpo and Yongdongpo most of the day. One Red plane crossed Seoul after I had seen my brood safely aboard the ship and had returned home to do some hasty packing for myself. The plane had just shot up the Yongdongpo airfield about three miles from our house and had then come in over town at a low level with guns blazing away. I had run out into the backyard to watch for a moment, but when I noted that our house was in the line of fire and observed tiles flying off the roof, I immediately returned to my packing, and with some enthusiasm. I finished with my two bags (no more allowed) and prepared for a potential night's rest. I had a good start towards that objective when I was called back to the Embassy for around-the-clock duty. I could hear the battle noise north of town as I drove downtown through the blackout.

"At the office I packed two briefcases with records of importance to our own military authorities, concerning petroleum stocks, facilities, condition and disposition in Korea, put terminal personnel to work filling drums with essential and inflammable petroleum products, for dispersal and easy access when needed, thus emptying the large storage tanks which had already been targets of air attacks.

"By 6:30 p.m. Tuesday this operation was essentially completed and I had destroyed my files except for the contents of my briefcases, which represented all that I know, and which I therefore felt I must salvage. Who wants to be uninformed when he is supposed to be an expert? At 7 a.m. it was decided to evacuate nonessential mission personnel, including all women employees who had been kept on the job. Transport planes and fighter escort had been ordered from Japan to evacuate this group from Kimpo airport. In spite of air attacks at Kimpo during this operation, all of this group were safely evacuated to Japan by noontime. Three of Uncle Joe's angels descended from the heavens to interrupt this operation, and continued right on down into the ground as a result of the active interest of our own F-80 fighters.

"As the above group were being assembled at the Embassy, I was told that because of my family status I was eligible to be included, and that I could leave with the group 'if I insisted.' So, I stayed on the job. By 9 a.m. Tuesday, the Reds had moved up to the outskirts of Seoul, and with tanks. Since the South Koreans had run short of ammunition, had no antitank guns, and no effective staff control, we knew that we must now take it on the lam, as it were. More transport plans were requested from Japan, and at 10:15 a.m. we took to the busses to rendezvous with the planes at Kimpo. During our last hour at Seoul, I joined a team swinging sledgehammers at the Embassy. We wrecked the radio station, telephone exchange and message center, and completed destruction of files with incendiary bombs which we set off in the piles of papers in the parking lot.

"I remember thinking at that point that I would feel much more like being evacuated if I could only have a shower. I was practically out on my feet, since as my children insist, I am an old man now. Even so, I had the situation right in the hollow of my head, just up to the level of the hole that penetrates it.

"I did get the shower though. A few minutes later after our motor convoy got underway headed for Kimpo. It was a shower of bullets from a Yak fighter that buzzed us right on the main drag in town. No one was hit in our convoy, but Koreans on the other side of the street were mowed down like grass. We had expected to be attacked as we were making the slow crossing of the long Han River bridge at the south edge of town since it had been jammed with refugees for hours, all heading south. It required 20 minutes to negotiate the crossing, after which we began to breath abnormally again.

"Five miles farther out I spotted another Yak bearing down on us from straight down the road. He passed over us at about 100 ft as I emptied my .38 at him, hoping to ruin his propeller and force him to crash. He didn't fire a single shot at us, probably because he had used up all his ammunition in shooting up Kimpo. We were all thank-

ful that he had beaten us to Kimpo.

"By 1:30 p.m. our own fighters appeared over Kimpo and set to work shooting down or chasing away all enemy aircraft within ten miles of the spot. Lots of planes, lots of action, and lots of noise, but poor visibility because of clouds. The transport planes came in promptly after the way had been cleared and by 4 p.m. we were all on our way to Japan, which is a very beautiful country at the end of June.

"I have been told that Tiff (apparently Carroll's son) distinguished himself on the ship, getting women and their luggage aboard and carrying small children up the ladder. He spent the night organizing and serving with the young men in white — a night bucket brigade, which was necessary because of the fact that there were only two single latrines on the ship, for some 700 women and children. Tiff and three of his strong-stomached pals carried the buckets from the live cargo hold to the rail and return, ad nauseum and ad infinitum. I was very proud of him. He wasn't spoiled after all — he just smelled that way.

"Maxie (another son apparently) naturally spent his waking hours in the radio room, and enjoyed the whole voyage. Julie helped entertain the 'little' children. Catharine just held back on her respiration and kept her mouth closed — a difficult feat for her, and one that distinguished her from the run of women aboard, many of whom pulled out all the stops, pulled the rank of their husbands, and complained to the captain about their accommodations. The gamut was just as long as regards the actions and reactions of the menfolk. I was amazed at some of them, and increased my respect for others, although few of the shots could have been called in advance. I could write a book about it.

"I feel, now, that since we saved our most precious possessions (our skins), I have no complaints, and I am angry only at the unnamed American who stole the two suits that I rescued, after I was safely billeted in Japan. All in all, though, I wouldn't have missed it for anything. I know myself better than ever, and so long as we live I know nothing else that happens to us will ever approach this experience in dramatic appeal, excitement and self-dependence in emergency.

"Later on, I hope to participate in the rehabilitation of Korea. It will be quite a job to put it back on its hands and knees, where it was on June 24, and a still greater job to get it all the way up on its feet." ★ ★ ★

Personals

W. H. STUEVE is retiring from his position as executive assistant of the Oklahoma Gas and Electric Co. after 25 years service. Upon retirement he plans to open an office in Oklahoma City, where he will continue writing for trade magazines, doing consulting work and serving as chairman of the New Industries Committee of the Oklahoma City Chamber of Commerce.

+

THAD RANDOLPH, sales manager of Oil Base, Inc., Compton, Calif., has been appointed to a vice-presidency of that company. Randolph will retain his duties as director of sales for Black Magic, White Magic, mud conditioning materials, mud guns, and all products manufactured by Oil Base, Inc. He succeeds J. A. MOORE, who has resigned from active participation but will remain on the board of directors.

+

FREDERICK H. CALLAWAY and WILLIAM H. WHEATLEY have been promoted by Stanolind Oil and Gas Co. at Tulsa. Callaway, formerly senior petroleum engineer, has been appointed reservoir engineering supervisor in the producing department, while Wheatley has been promoted from inspection supervisor to senior mechanical engineer in the manufacturing department. Both men have been with Stanolind since 1946.

+

BEN A. ELMDAHL has been appointed to the Board of Directors of Core Laboratories, Inc., Dallas, Tex. At the same time, J. W. BARBOUR, JR., of Oklahoma City, Okla., has been elected a vice-president of the firm.

+

BARNEY M. BYRNE is now employed as a petroleum engineer with Fidelity Oil & Royalty Co., Houston, following graduation at Texas A&M.

+

G. J. DECKER, who was on a temporary assignment in Edmonton, Canada, for Schlumberger Well Surveying Corp., has returned to the United States. He has been promoted to the position of Kansas division manager for Schlumberger and will be located in Wichita, Kans.

W. DON DE GEER, JR. is now employed as a trainee petroleum engineer for the Globe Oil & Refining Co., Wichita, Kans.

+

J. BILLY EVANS is working as district superintendent for the Union Oil Co. of California, Houston, Tex.

+

C. MARKS HINTON is now manager of production for the American Republics Corp., Houston, Tex.

+

H. L. KIRKPATRICK, petroleum engineer, is merging with T. W. MCGUIRE to form the firm of Kirkpatrick & McGuire, Shreveport, La.

+

WARREN E. LATIMER is now a junior petroleum engineer with the Ohio Oil Co., Oblong, Ill.

+

G. E. MCCLATCHEY, formerly drilling engineer in charge of offshore operations for Barnsdall Oil Co., became division engineer for the tri-state division (Arkansas, North Louisiana, East Texas) of Sunray Oil Corp. Barnsdall Oil Co. and Sunray have merged to one concern.

+

RICHARD R. NEWTON is employed as a petroleum engineer for the Smith Newton Oil Co., Bradford, Pa.

+

EDMOND F. SMIGEL has been promoted to production superintendent of the Ohio Oil Co., Sidney, Neb., working in conjunction with the development of newly discovered oil fields. He was formerly with the engineering department.

+

JOHN C. WRIGHT is now a petroleum engineer with the Wiser Oil Co., Sistersville, W. Va.

+

JOHN C. CALHOUN, JR. has been appointed chief of the petroleum and natural gas division at the School of Mineral Industries, Pennsylvania State College. He was formerly chairman of the School of Petroleum Engineering at the University of Oklahoma.

ACIDIZING FUNDAMENTALS

Continued from Page 14, Section 1

tive agents can be used to minimize the effect of the acid insoluble materials.

Since there is such a large number of factors to be considered in the acidizing process no one chemical additive is satisfactory under all conditions. There are many fields in which certain chemical additive agents are of value and there are other fields in which these same chemical additives are of little, if any, help. The theory itself on which the use of chemical agents is based is not fallacious; it is only the reasoning concerning the theory which becomes fallacious, such as when we consider the use of a chemical agent under all conditions, regardless of whether or not it is applicable.

The use of the present chemical additive agents is not to replace such mechanical aspects as stage treating, low and high injection rates, small and large gallonage treatments and mechanically controlled treating. The additive agents, when required, are to be used in conjunction with these various techniques. There are chemical additive agents being developed now which can perform certain types of control treatments, also to obtain the benefits of large gallonage treatment from the use of only a relatively small amount of acid.

The question as to the efficiency of inhibitors above 150°F can only be answered in respect to the materials which are being considered as inhibitors. There are many inhibitors now being used in the acidizing process which are unsatisfactory for use above 150°F. Among the materials which probably should not be used above this temperature are the nitrogen base, coal tar materials, the organic thiourea compounds, and the inorganic inhibitors containing copper. There are inhibitors which are applicable above this temperature and can be used successfully to protect steel at temperatures as high as 300°F. ★ ★ ★

AUTHOR'S REPLY TO P. H. CARDWELL

This discussion overlooks the distinction, made in the paper, between what the writer termed "chemical" and "physical" additives. The agents termed "chemical" in the discussion are the "physical" additives described in the paper. No clear point is presented concerning the "chemical" agents except the statement regarding the theory of their use.

To conscientiously advocate the use of "chemical" additives it is necessary to assume the rock formation to be of uniform chemical composition. As pointed out in the paper, acid penetrates only secondary channels. These channels are generally lined with and partially or wholly plugged with secondary material the chemical composition of which may or may not resemble that of the matrix. The obvious difficulty of analysis under these conditions makes equally obvious the fallacy of reasoned attempts to control any phase of the reaction by chemical means.

The second point overlooked in the discussion is the effect of the time element with regard to inhibitor efficiency. A number of inhibitors, including the inorganic type containing copper, will protect steel at high temperatures for a few hours. Recorded cases of material damage to tubing, drill pipe, and casing, together with expert testimony from litigation in which inhibitors were involved indicate that the uncontrolled performance of any inhibitor in a well does not always resemble the controlled performance observed in the laboratory. ★ ★ ★

AIME Past President S. A. Taylor Dies

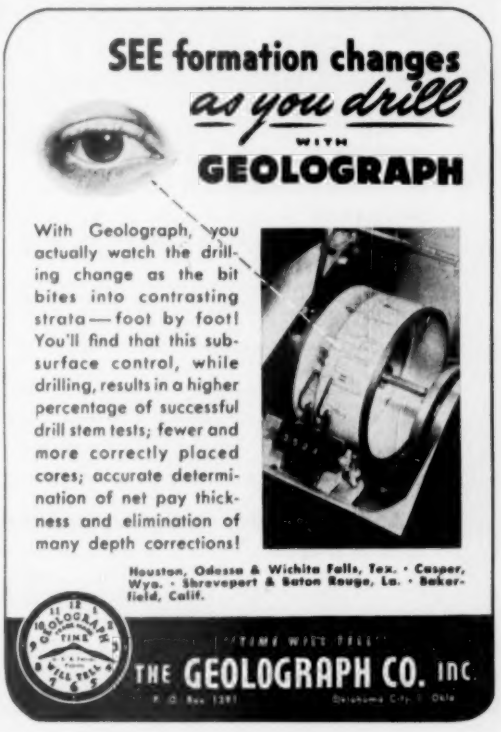
Ending 62 years of devotion to his profession, the Institute's 47th President, Samuel Alfred Taylor, died on August 20th after a brief illness at his home in Pittsburgh, Pa. While his active interests in engineering and coal mining were broad in an international sense, he was a leader in the educational, religious, and civic development of his native community.

A western Pennsylvanian throughout his 86 years, Taylor was born in North Versailles Township, on October 24, 1863. Educated locally, he graduated from Western University of Pennsylvania, now University of Pittsburgh, in 1887 with the degree of Civil Engineer and at the same university was awarded the degree of Doctor of Science in 1919. Taylor served as Vice-President of its Board of Trustees for many years. He acted as Dean of its School of Mines from 1910 to 1912, inclusive, while continuing his consulting practice.

Before establishing his consulting practice in Pittsburgh in 1905, Taylor served in many phases of structural, municipal, and mining engineering and was employed in the engineering departments of Carnegie Steel Co. and the Pennsylvania Railroad.

Mr. Taylor joined the AIME in 1905. His term as President of the Institute in 1926 marked the substantial beginning of active interest by coal mining engineers in Institute affairs. He served as an Institute Director from 1915 to 1920, inclusive, and again in 1927 and 1928. At his death, he ranked next to Herbert Hoover as the Institute's senior Past President.

Previously, Taylor had been President of the Coal Mining Institute of America in 1911, of the American Mining Congress in 1912, and of the Engineers' Society of Western Pennsylvania in 1913.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Proposed for Membership

Petroleum Branch

Total AIME memberships on June 30, 1950, was 16,339; in addition 4,256 Student Associates were enrolled.

ADMISSIONS COMMITTEE

A. J. Phillips, Chairman; George B. Carless, John T. Sherman, Lloyd C. Gibson, R. D. Mallison, Plato Malozemoff, Ivan Given.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status; R, reinstatement; M, member; J, Junior Member; AM, Associate Member; S, Student Associate; F, Junior Foreign Affiliate.

ARIZONA

Coolidge—Schoonover, Floyd E. (J).

ARKANSAS

Little Rock—Risley, Edyth C. (J).

CALIFORNIA

Bakersfield—Bourne, William H. (C/S-S-J); Wells, Gordon H. (M).
El Cerrito—Miller, Frank G. (C/S-J-M).
Long Beach—Ennis, William W. (M); Wright, Alfred Claude (J).
Oxnard—Larson, Robert Reynold (J).

ILLINOIS

Chicago—Lang, William Gerry (J).
Peoria—Schattel, Kenneth F. (M).

INDIANA

Washington—Jones, John A. (C/S-S-J).

KANSAS

Paola—Gardner, Dan Lewis (J).

LOUISIANA

Baton Rouge—Gandy, Harvey Martin (J).
Donaldsonville—Fillman, Jack M. (R,C/S-S-M).
New Orleans—Alexander, Granison T., Jr., (J); Watson, Richard A. (J).
Shreveport—Clark, William Howard (J); Pickrell, William S. (J).

NEW MEXICO

Hobbs—Wilkie, David B., Jr., (C/S-S-J).
Roswell—Shepard, Robert H.

OHIO

Lancaster—Stear, David S. (C/S-S-J).

OKLAHOMA

Lawton—Bull, Kenneth W. (C/S-S-J).
Oklahoma City—Roy, Willard L. (R,C/S-S-J).
Pauls Valley—Bass, William Robert (J).
Tulsa—Bridges, Philip M. (J).

PENNSYLVANIA

Uniontown—Burwell, William H. (J).

TEXAS

Austin—Cocke, Robert R., III, (C/S-S-J).
Beaumont—Cornelius, George L. (R,C/S-S-M).
Corpus Christi—Webb, Austin C. (J).
Dallas—Fennell, Lawrence S. (M); Livingston, Mickey M. (M); Stiff, Henry A., Jr. (M).
Gonzales—Deschner, Henry William (J).
Grand Prairie—Staub, Harrison Lee (J).
Houston—Cloninger, James S. (C/S-S-J); Holloway, Harry H. (R,C/S-J-M); Manly, Eugene Decker (J); McCardell, William M. (J); Swingle, Michael Patrick (J); Taylor, Fred W. (C/S-S-J).
Iraan—Kearley, William M., Jr. (C/S-S-J).
McKinney—Standley, Milton Howard (J).
Midland—Kellerman, Robert E. (J); Rowan, Robert L., Jr. (J); White, Samuel E. (R,C/S-S-M).
Odem—Holifield, F. H. (C/S-S-J).
Odessa—Harper, Jackson B. (J).
Wink—Welch, David P. (J).

WASHINGTON, D. C.

Washington, D. C.—Aboul-Seoud, Hasean H. (J); Heilborn, George (J).

WYOMING

Casper—Emery, Wilson B. II (J).

CANADA

Calgary—Nichols, Norval W. (M).

VENEZUELA

Jusepin—Edison, Thomas O. (J).

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REGULAR TYPE—This instrument is favored because of its simplicity of operation. The drilling crew can load, unload, and develop the recording discs in daylight. The discs are easy to read and simple to interpret. It is the most dependable survey instrument available.

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2. To accurately record the course of the well as it is drilled in order to straighten the bore if necessary.
3. As a means of securing information to insure correct bottom hole spacing on a lease.
4. For determining the correct location of all points in the well in reference to the geological structure.
5. In orienting cores to correct for the true drift and deviation of the well bore.

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TYPE "W" DRIFT INDICATOR—The Type "W" is a mechanical instrument which eliminates the use of batteries, light bulbs, and photo sensitive discs. The instrument incorporates a patented self-checking design which enables it to make two recordings. This feature insures that an incorrect reading will not be accepted.

TYPE "M" DRIFT INDICATOR—This instrument records photographically, and due to the length of the exposure necessary to make a recording, the operator is assured of a true reading. If the instrument's plumb bob is in motion, no record is obtained.

These instruments are used—

1. To determine that the well is drilled within the drift limits specified in the contract.
2. As an assurance that there are no "doglegs" left in a straight well after it is drilled.
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1950 IS OUR 20TH ANNIVERSARY YEAR

Employment Notices

The JOURNAL will post notices of men and jobs available. Companies and AIME members are invited to use this space, for which there is no charge. Except as noted below, address replies to: Code (appropriate number), JOURNAL OF PETROLEUM TECHNOLOGY, 601 Continental Bldg., Dallas 1. Show return address on envelope. These replies will be forwarded unopened and no fees are involved.

Replies to the personnel coded M-580 below should be addressed to: Engineering Societies Personnel Service, 8 West 40th St., New York 18, N. Y. The ESPS, on whose behalf these notices are published here, collects a fee from applicants actually placed.

POSITIONS

♦ Petroleum technologist, skilled particularly in reservoir engineering, production, and drilling. Must be recognized authority in the field with outstanding record of accomplishment and acquaintance in the industry. To assume responsibility for and be director of Petroleum Technology Division for research organization. Code 522.

PERSONNEL

♦ Petroleum engineer, age 52 and now eligible for retirement after 26 years' service with one major oil company, desires employment or business connection with independent operator, bank or royalty owner in or near Dallas, Tex. Experienced all phases oil business, construction, maintenance and operations, including gasoline plants, repressuring, pipelines and pumpstations. Will be available for personal interview in Dallas last two weeks of September. Code 138.

♦ Geologist, 27, married, fluent Spanish, graduate Lehigh University, one year graduate work Johns Hopkins University. Some mining experience. Two years petroleum explorations Colombia, mapping, drafting, developing geological data, assisted supervision 20 laborers. Seeks foreign, domestic position as field or subsurface geologist, petrographer, mineralogist, mining geologist, geological draftsman. Six-month single status. M-580.

♦ Physicist, Ph.D., chiefly interested in research, more than 10 years' experience in oil industry, academic and government work, is looking for position, preferably on West Coast. Code 139.

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Young Will Direct 1951 Annual Meeting

The AIME Annual Meeting will be held in St. Louis, Mo., Feb. 19-22, 1951, under the general chairmanship of Howard I. Young, director of AIME and president of the American Zinc, Lead & Smelting Co. Secretary for the meeting is Fred J. Meek, plant engineer of the American Zinc Co. of Illinois. The committees have been chosen, and work is underway to complete all necessary details.

The major part of the planning will be done by members of the St. Louis Section. Papers for presentation will be selected by the Technical Publications Committee. The program schedule will be arranged by the Coordinating Committee on Technical Programs for the Annual Meeting, under the chairmanship of S. J. Swainson. Present plans call for a student forum under the guidance of faculty sponsors of student chapters. Because of the large program, some technical meetings will be held at the Hotel Jefferson (headquarters hotel), and some, including those of the Metals Branch, will be held at the Hotel Statler. ★ ★ ★

Book Reviews-

ELEMENTS OF OIL RESERVOIR ENGINEERING

By Sylvain J. Pirson, McGraw-Hill Book Co., New York, Toronto, London, 1950. 441 pp., illus., diagrs., charts, maps, tables, 9¼ x 6¼ in., cloth, $6.50.

A graduate-level text for petroleum engineers, this book develops and coordinates the principles which govern the behavior of geological petroleum reservoirs when placed under protection during their primary phase and during the application of external sources of energy as practiced in secondary recovery operations. The discussion develops the concepts of three fundamental production processes—water, segregation, and depletion drives, which may operate singly or in combination.

Each oil-production mechanism is shown to have a particular recovery efficiency which may be determined from a knowledge of the reservoir fluids and rock characteristics. Recent advances in the methods of testing properties of reservoir rocks and reservoir fluids are covered. ★ ★ ★

PETROLEUM CHEMICALS INDUSTRY

By R. F. Goldstein with a foreword by Sir R. Robinson, John Wiley & Sons, New York; E. & F. N. Spon, Ltd., London, 1950. 449 pp., diagrs., charts, tables, 9¾ x 6 in., cloth, $8.50.

This book covers a wide range of subjects dealing with the manufacture of synthetic organic chemicals from petroleum. Chapter I deals with the hydrocarbons present in petroleum or produced as by-products. Chapters 2-5 treat the chemistry of paraffins. In chapters 6-10, the manufacture of olefins and the chemical developments based on them are covered. The manufacture of other classes of hydrocarbons is discussed in chapters 11-14, while the manufacture and reaction of the principal classes of petroleum chemicals is considered in chapters 15-19. A summary of the chemical by-products is presented in chapter 20. Numerous references to periodical literature, patents, and German Intelligence Reports are made as footnotes throughout the text. ★ ★ ★

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601 Continental Building
Dallas, Texas

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ABSTRACTS

Continued from Page 21, Section 1

drilling fluids on their carrying capacities. The paper deals with these conclusions: Turbulent flow in the well annulus is most desirable from the standpoint of cutting removal; low viscosity and low gel are advantageous in removing cuttings; increase in mud weight is effective in increasing carrying capacity; the carrying capacity is higher when the pipe is rotated than when it is not; if turbulent flow can be maintained, an annular velocity slightly higher than the slip velocity of the largest cuttings to be transported should keep the bore hole clean.

61-G
A Modified Low-Strength Cement

B. E. Morgan and **G. K. Dumbauld,** Humble Oil and Refining Co., Houston, Tex.

The need for a low-strength cementing composition for use in well cementing is reviewed, and results are presented of laboratory and experimental field tests of a modified cement having a controlled ultimate tensile strength of approximately 200 psi. The modified cementing composition may be prepared from either high early strength or normal portland cements by the addition of bentonite clay and a suitable agent for dispersing and controlling the set of the slurry. Substitution of the modified cement for conventional slow-set cements may give better completion results in many wells because modified cementing composition has lower set strength, lower slurry density, and greater slurry stability than conventional cement slurries.

62-G
A Report on Penetration Rates for Directional Drilling Operations

Gordon Jackson, Vice-President and General Manager, Eastman Oil Well Survey Co., Denver, Colo.

This paper is a quantitative progress report on directional drilling operations throughout the United States. An analysis of the drilling data by regions is illustrated through the use of penetration curves and accompanying graphs. The fundamental data on which the drilling curves and information are based were gathered from special drilling reports on nearly one million ft of directionally drilled hole and 405 individual wells. The study has been continuous over a period of four years and illustrates many avenues for improvement, and also definitely demonstrates the progress which is being made in directional drilling operations.

63-G
Applications of Oil Emulsion Muds in Louisiana

J. W. Walters and **L. W. Nichols,** The California Co., New Orleans, La.

The paper covers the application of oil emulsion mud in drilling in North Louisiana, and directional drilling in South Louisiana. Data are presented showing relative economics of oil emulsion mud versus conventional base mud with respect to rock bit and drilling costs. Data are presented showing reduced torques and safety features of fishing in high angle directional holes in South Louisiana.

Field Performance Under Fluid Injection

64-G
Primary High Pressure Water Flooding in the Pettit Lime Haynesville Field

D. W. Akins, Jr., The Ohio Oil Co., Shreveport, La.

The case history of a combination gas and water flood instituted early in the life of a field is described. It was recognized from the beginning that recovery would be low, under normal production methods, from the several separate, thin beds of porous limestone which had such poor native permeability that the wells would not produce without acidizing. It is thought that the combination flood gives excellent recovery efficiencies for this type of reservoir. Present estimates are that ultimate recovery will be approximately double the recovery expected under the original solution gas drive mechanism.

65-G
Preliminary Results of Pilot Water Flood of Hunton Limestone, Graber Pool, Kansas

M. H. Dubrow, W. E. Landrum and **H. L. Temple,** Continental Oil Co., Houston, Tex.

Although water flooding of sandstone reservoirs has been practiced extensively and adequately reported in technical literature, water flooding of essentially depleted limestone reservoirs has not received a great deal of attention; and data on such projects are rather scarce. This paper deals with the encouraging results obtained from a pilot water flood of the Hunton Limestone in the Graber Pool, Kansas. The program, involving the injection of fresh water into a single flank well, commenced in January, 1947. Results to date have indicated that sufficient additional oil recovery can be obtained from flooding the Hunton Limestone to warrant strong consideration of water flooding as a means of increasing the economic oil recovery from similar essentially depleted solution gas drive limestone reservoirs.

66-G
The Southwest Antioch Gibson Sand Unit

T. E. Ockershauser, The Globe Oil and Refining Co., Oklahoma City, Okla.

The Southwest Antioch Field, located in Garvin County, Oklahoma, was discovered in February, 1946, and produced oil at a depth of 6,525 ft in a lower Pennsylvanian sandstone, locally called "Gibson" or "Third Deese." This unit was formed with 67 wells drilled on a 40-acre pattern, April 1, 1948, under provisions of the compulsory unitization law of Oklahoma. The unit now contains 137 wells. Gas at approximately 2,400 lb has been returned to the reservoir since August, 1948, through seven injection wells at high structural positions on the east side of the pool. Gas-oil ratio is much lower and reservoir pressure is substantially higher than they otherwise would be compared to an adjoining non-unitized area.

67-G
The Shuler-Jones Sand Reservoir — Nine Years of Unitized Gas Injection

Herman H. Kaveler, Jack Turner and **Walter R. Evans,** Phillips Petroleum Co., Bartlesville, Okla.

This reservoir was discovered in September, 1937, unitized in February, 1941, subjected to gas injection in July, 1941, and water injection in July, 1944. A cumulative recovery amounting to 50 per cent of the total 100 million bbl of oil originally in place has been made possible by the unitized pressure maintenance operations. Current production averages 6,675 B/D, more than 60 per cent of which is by natural flow. About one-half the original reservoir pressure of 3,500 psi was lost in producing 16 million bbl of oil prior to unitization. Since, 34 million bbl have been produced with the additional loss of only 200 psi in reservoir pressure.

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American Petroleum Institute *Sullivan, Stauffer, Colwell & Bayles, Inc., New York*	Sec. 1—27
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Lufkin Foundry & Machine Co. *Cudlipp Advertising Agency, Lufkin, Tex.*	Sec. 1—1
Menlo Research Laboratory *Sturges and Associates, San Carlos, Calif.*	Sec. 1—7
Oil Base, Inc. *Dozier-Graham-Eastman, Los Angeles, Calif.*	*
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Professional Services	Sec. 1—2
Schlumberger Well Surveying Corp. *Rives, Dyke & Co., Houston, Tex.*	Second Cover
The Geolograph Co., Inc. *Lowe Runkle Co., Oklahoma City, Okla.*	Sec. 2—3
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PETROLEUM BRANCH MEETING CALENDAR

SEPTEMBER Through FEBRUARY

SEPTEMBER

7	Illinois Basin Chapter
11	Mid-Continent Section
12	Delta Section
13	Southwest Texas Section
14	Pacific Junior Group
19	Gulf Coast Section
20	Kansas Section
21	South Plains Sub-Section
21	Oklahoma City Section
22	Mississippi Sub-Section
25	Pacific Petroleum Chapter
25	Permian Basin

OCTOBER

4-6	**Petroleum Branch, AIME, New Orleans**
5	Illinois Basin Chapter
9	Mid-Continent Section
9-13	Mineral Economics Division, Washington, D. C.
11	Southwest Texas Section
12-13	**Petroleum Branch, AIME, Los Angeles**
17	Gulf Coast Section
18	Kansas Section
19	South Plains Sub-Section
19	Oklahoma City Section
23	Pacific Petroleum Chapter
30	Permian Basin

NOVEMBER

2	Illinois Basin Chapter
8	Southwest Texas Section
13	Mid-Continent Section
14	Delta Section
15	Kansas Section
16	South Plains Sub-Section
16	Oklahoma City Section
21	Gulf Coast Section
27	Pacific Petroleum Chapter
27	Permian Basin Section

DECEMBER

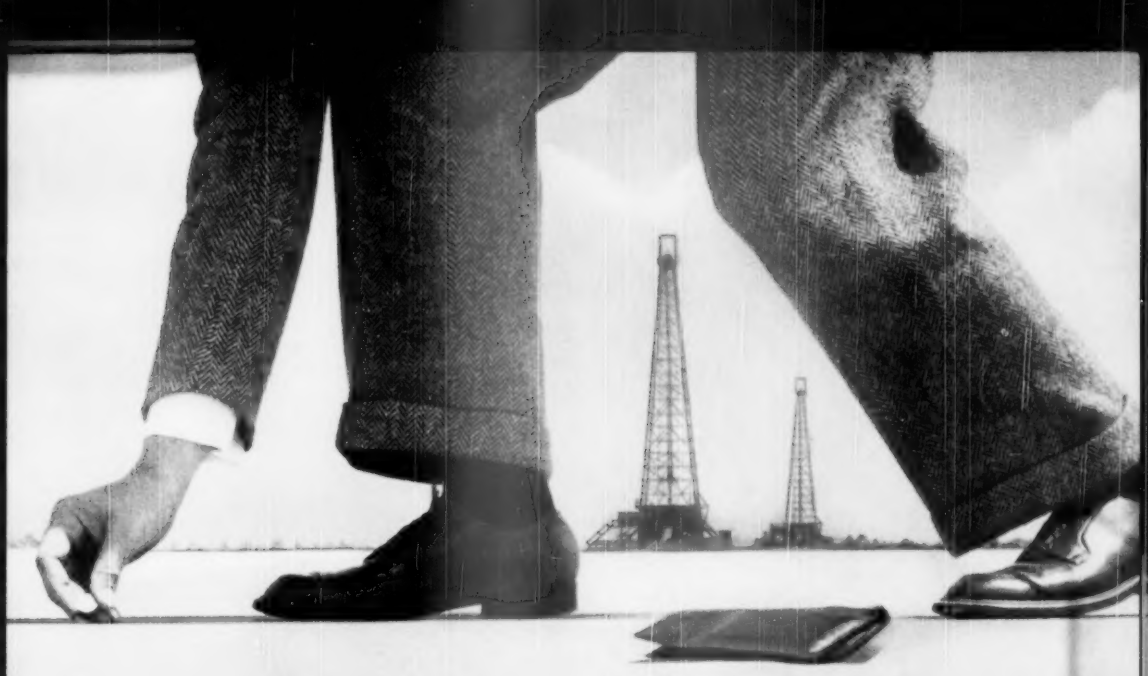
1-2	Joint Meeting, Texas Local Sections, Texas Technological College, Lubbock.
1	Mississippi Sub-Section
7	Illinois Basin Chapter
11	Mid-Continent Section
12	Gulf Coast Section
12	Delta Section
14	Pacific Junior Group
20	Kansas Section
21	South Plains Sub-Section
21	Oklahoma City Section

JANUARY

4	Illinois Basin Chapter
8	Mid-Continent Section
9	Delta Section
10	Southwest Texas Section
17	Kansas Section
18	Oklahoma City Section
22	Pacific Petroleum Chapter

FEBRUARY

1	Illinois Basin Chapter
12	Mid-Continent Section
13	Delta Section
14	Southwest Texas Section
15	South Plains Sub-Section
15	Oklahoma City Section
19-22	AIME ANNUAL MEETING, St. Louis, Mo.
26	Pacific Petroleum Chapter



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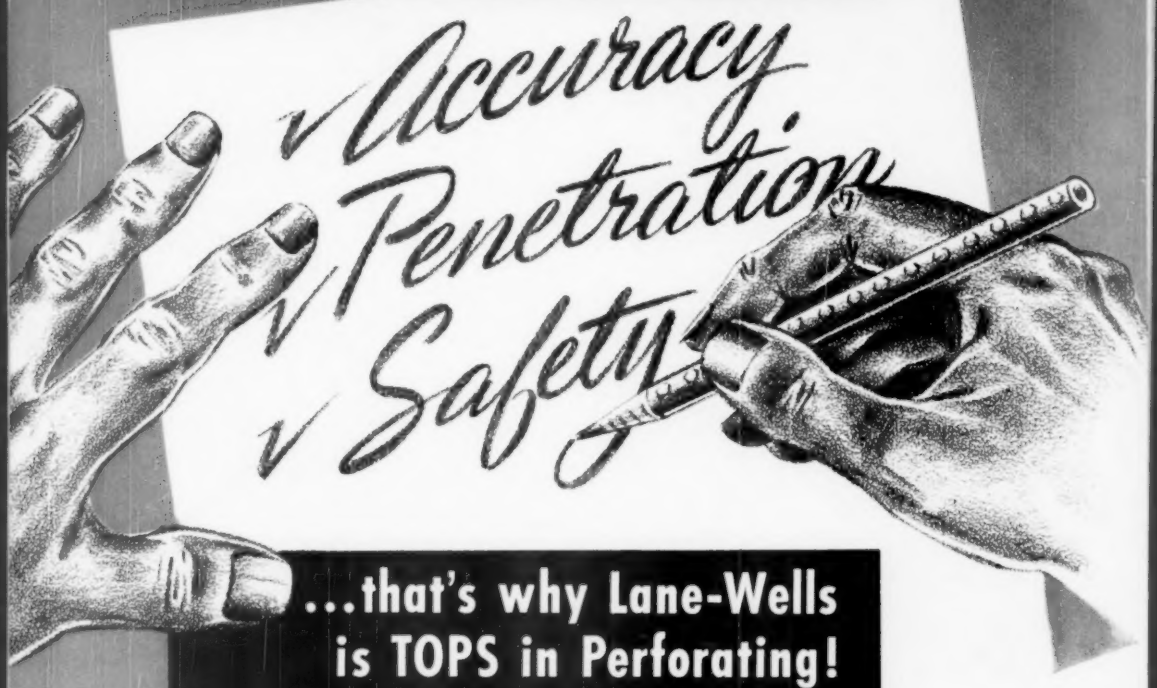

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